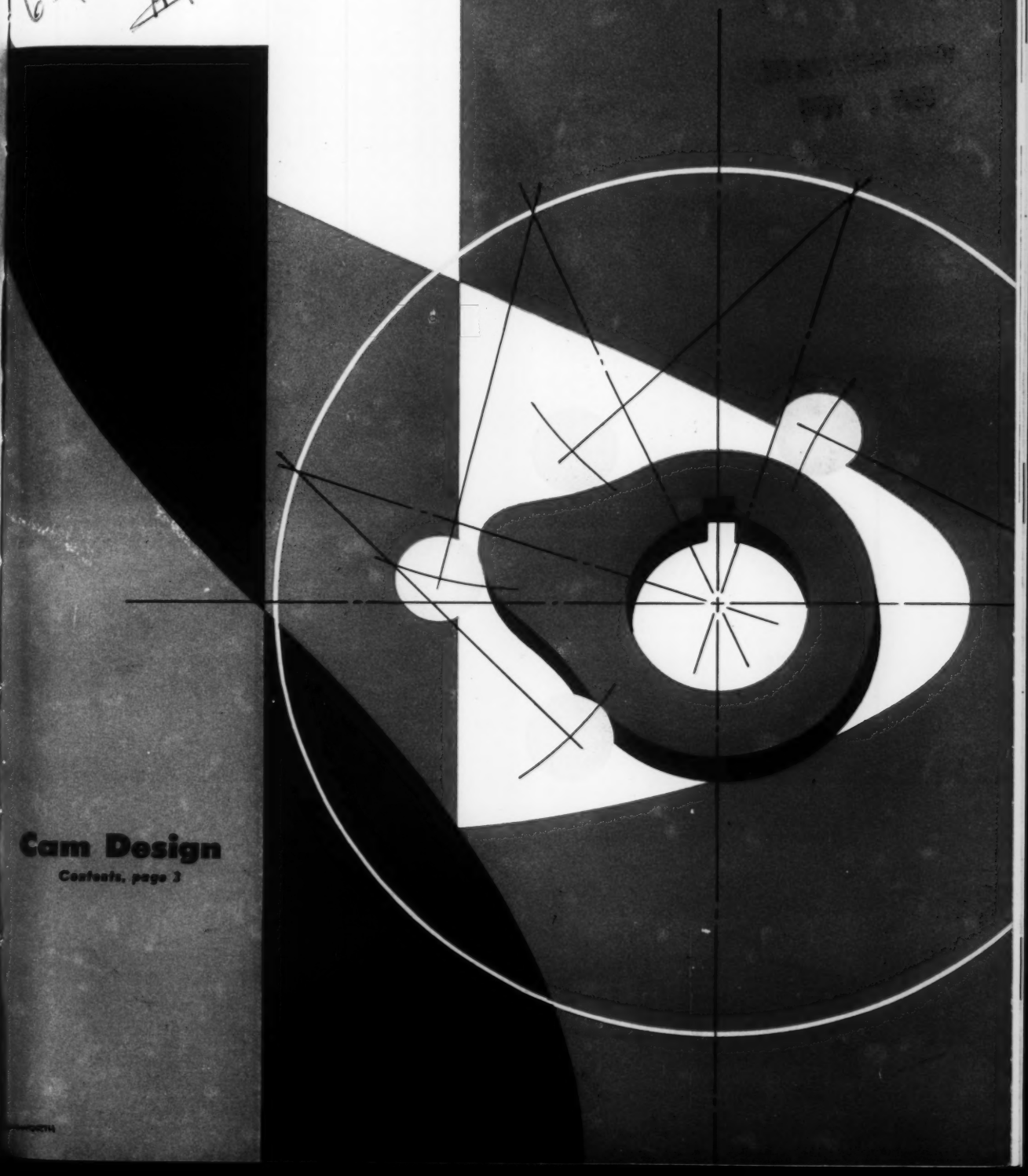
NOVEMBER 1, 1956
EVERY OTHER THURSDAY

MACHINE DESIGN

A PENTON PUBLICATION



Cam Design

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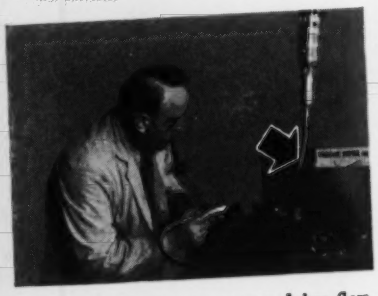
FLEXIBLE SHAFT IDEAS for ENGINEERS

How fast can a power drive flexible shaft be operated?



GENERALLY SPEAKING power drive flexible shafts are designed to operate at speeds of 1,750 to 15,000 rpm. However, there are many applications where higher speeds are attained especially in the case of small diameter shafts.

Pictured is a portable tool in which an S. S. White flexible shaft operates at speeds up to 45,000 rpm. According to the manufacturer, the success of the application is due to the "very high operating speed and excellent torque transmission possible through the flexible shaft . . . which runs cool and without vibration."

High speed remote control flexible shafts meet many requirements

WHEN TRANSMITTING CONTROL to parts through small reversible electric motors, the use of high speed remote control flexible shafts should definitely be considered.

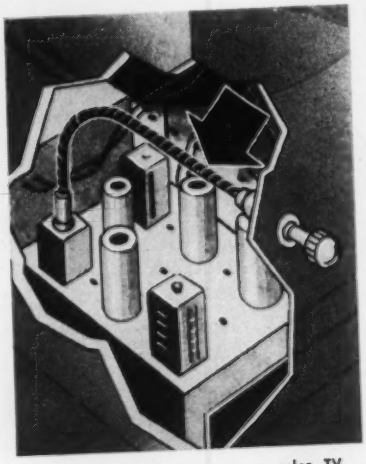
These shafts have been especially developed for intermittent operation in either direction of rotation at speeds up to 3,000 rpm.

But, their ability to operate around turns, the ease with which they can be installed, and their compactness offer definite advantages for many industrial applications.

We'll be glad to send details if you write stating your requirements.

Flexible Shafts offer big advantages when power or control goes around turns

Eliminating design and installation problems saves time and costs and improves performance

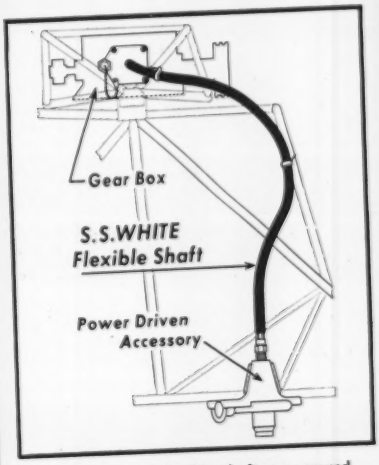


Regulating hue contrast on a color TV receiver is simplified by a flexible shaft coupling between control knob and circuit element. Note 90° turn.

ONE OF THE IMPORTANT ADVANTAGES of a flexible shaft is its ability to operate around turns and under conditions where alignment difficulties make a solid connection either impractical or uneconomical.

This fact is of prime importance when working out any design where power or control has to be transmitted between two parts. It assures greater design freedom. It simplifies manufacturing and assembly procedures. And it brings about important savings in costs as well as improvements in performance.

The two illustrations above graphically illustrate how S. S. White flexible shafts provided effective, cost-saving solutions to two power and control problems.



A power drive flexible shaft, run around intervening struts and frames, provides a dependable easy-to-install drive for a helicopter pump.

Think of your own equipment. Can you see where you could improve it through the use of flexible shafts? Our engineers will be happy to cooperate with you in making recommendations. There's no obligation, of course.

USEFUL FLEXIBLE SHAFT DATA

Bulletin 5601 has concise information on how to select and apply flexible shafts. Send for a copy.

FS-3

FIRST NAME IN FLEXIBLE SHAFTS

S.S.White

S. S. WHITE INDUSTRIAL DIVISION, DEPT. 4, 10 EAST 40th ST., NEW YORK 16, N.Y.

Western Office: 1839 West Pico Blvd., Los Angeles 6, Calif.

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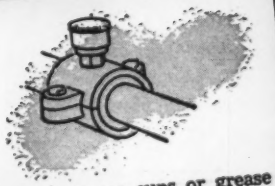
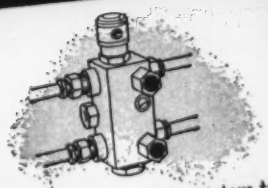
Meets **toughest** lubrication requirements!

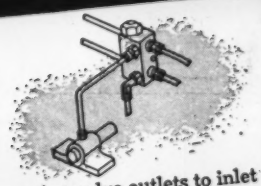
Can be designed into any machine, in **4 easy steps**



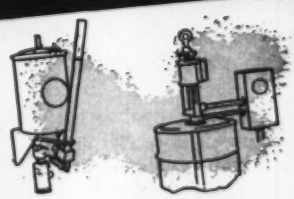
1. Remove grease cups or grease fittings.



2. Connect each valve in system to its two lubricant supply lines.



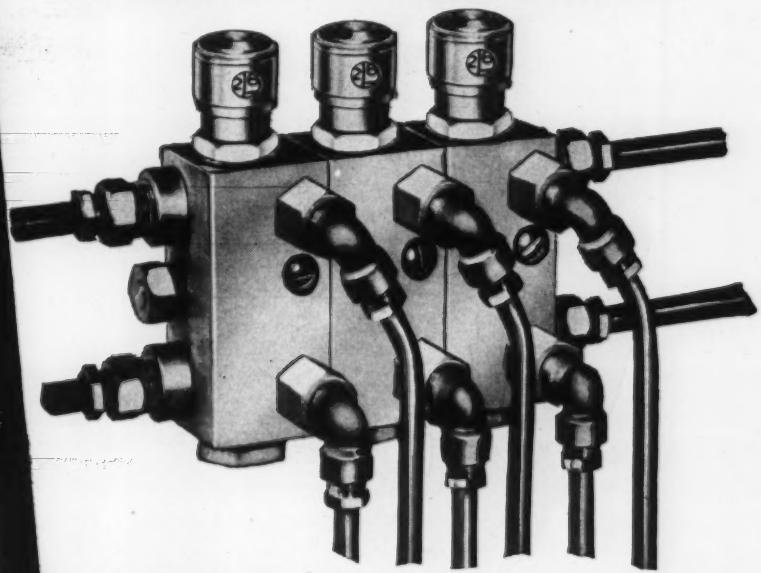
3. Connect valve outlets to inlet of bearings. (Each valve serves two bearings.)



4. Provide central pump for supplying lubricant to system.

ALEMITE Accumatic®

CENTRALIZED AUTOMATIC LUBRICATION



Alemite Type II Accumatic Valves meet big-volume requirements . . . handle difficult multiple-bearing lubrication under all conditions. Fully sealed for *clean* lubrication of power shovels, cement kilns, conveyors – any outdoor or indoor installation. Operate whether completely immersed in fluid . . . covered by dirt or grit . . . or protected by anti-corrosive paint. For fluid oil or light grease. Four sizes, delivering from .050 to .500 cu. in. of lubricant. Fully hydraulic – no springs to adjust or replace.

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A PRODUCT OF SW STEWART WARNER

Circle 504 on page 19

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THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

November 1, 1956
Volume 28—No. 22

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Subscriptions in United States, possessions, and Canada for home-addressed copies and copies not qualified under above rules: One year, $10. Single copies $1.00. Other countries: One year, $25. Published every other Thursday and copyrighted 1956 by Penton Publishing Co., Penton Bldg., Cleveland 13, Ohio. Accepted as Controlled Circulation publication at Cleveland, Ohio.

When requesting changes of address, etc., please allow four to six weeks for processing.

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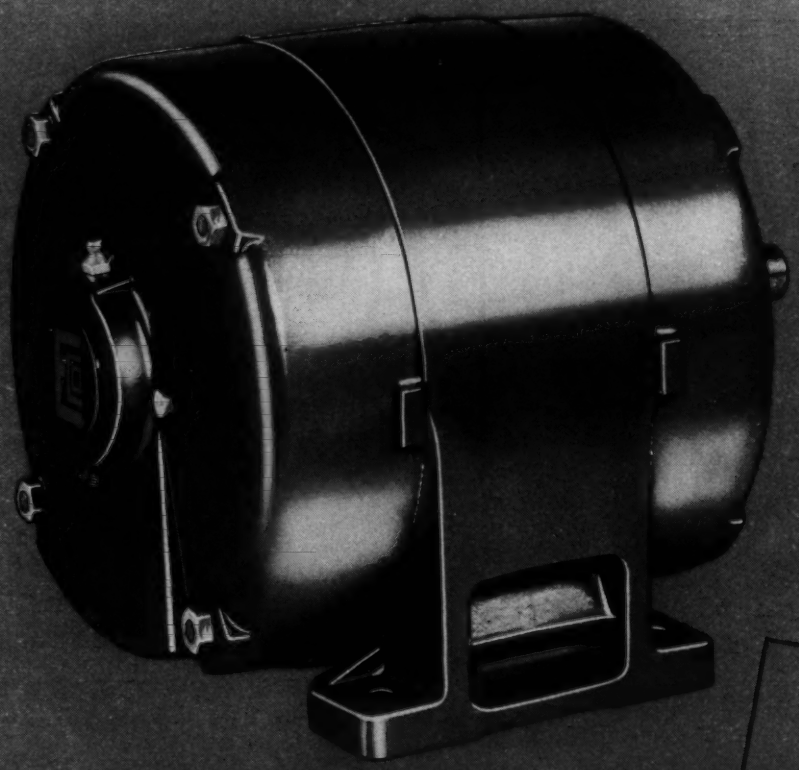
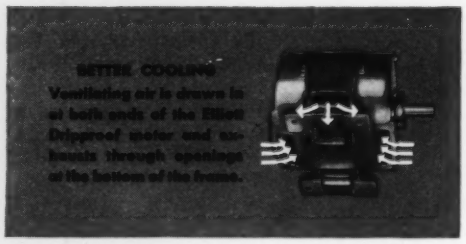
XUM

Inside and Outside . . . entirely new



the NEW Elliott C-W Dripproof Motor

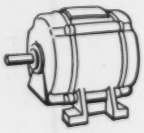
BALANCED DESIGN assures dependable performance


BETTER COOLING
Ventilating air is drawn in at both ends of the Elliott Dripproof motor and exhausts through openings at the bottom of the frame.

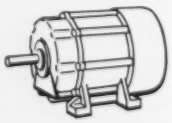
The *balanced* design of the new Elliott C-W type N motors provides the *best* in mechanical protection, the *best* in insulation, the *best* in bearings, the *best* in rigid construction. These motors produce more horsepower per pound, require less space, less maintenance, have longer service life. Every rotor is dynamically balanced. Rigid cast frames assure correct alignment, resist corrosion and mechanical abuse. Highly effective cooling eliminates troublesome hot spots.

The design illustrated above is dripproof—and virtually splash-proof as well. Yet ingenious design has provided ample passages for cooling air. Other types of enclosures providing even greater protection are available for service where conditions are extremely severe.

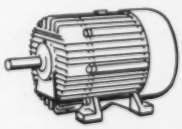
OTHER C-W TYPE N MOTOR ENCLOSURES



Totally-enclosed non-ventilated



Totally-enclosed, fan-cooled Frames 256 U and smaller



Totally-enclosed, fan-cooled Frames 284U-326U

ELLIOTT Company

CROCKER-WHEELER DIVISION

For complete details, send for new booklet. *WRITE* Elliott Company, Crocker-Wheeler Division, Jeannette, Pa.

W6-5

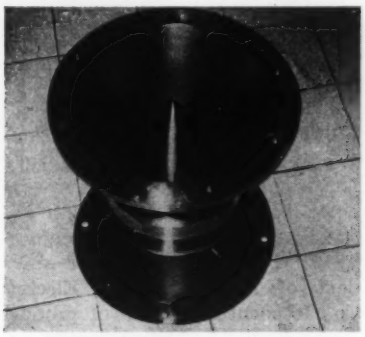
Circle 506 on page 19

Engineering News Roundup

Device Provides Ultrasonics For Processes, Fog Control

METUCHEN, N. J.—A new ultrasonic device may solve the problem of fog dissipation at airports and highways and greatly improve industrial processes such as radioactive waste disposal, concentration of fissionable ores, precipitation of aerosols and dust particles, cleaning, sterilization, and the mixing of paints.

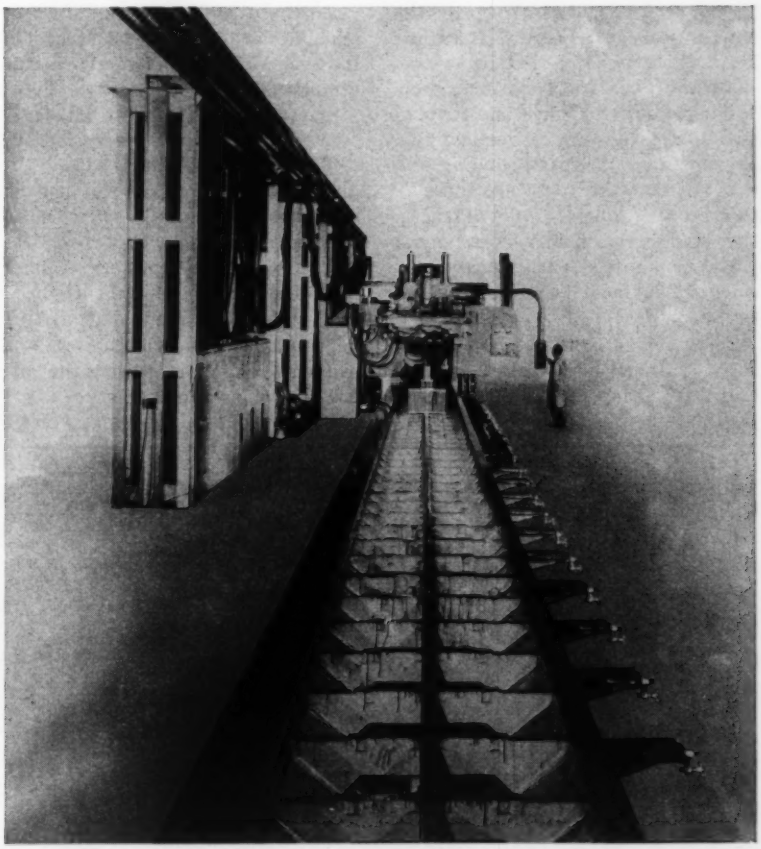
The instrument, named Multiwhistle Air-Jet Ultrasonic Generator, is a very high intensity source of sonic energy ranging from 4 to 40 kc. It can be operated in either gas or liquids and may be used in corrosive atmospheres or in temperatures as high as 1290 F. There



Industrial ultrasonic generator is being studied for fog control.

are no moving parts or electronic components. An air compressor or steam generator furnishes the driving power which is converted to ultrasonic energy with an efficiency greater than 20 per cent.

The Multiwhistle will be manufactured and marketed in the U. S. by Gulton Industries Inc. under an agreement with a French firm which originated the design. The French Air Force is currently testing Multiwhistle for the dissipation of fog.



The world's first electronic tracer-controlled spar mill provides work area for parts up to 60 ft long and 35 in. wide. Four milling heads operating singly or in combination are capable of 12 different head motions.

Big Spar Mill Is First Electronic Tracer Controlled

CHICAGO, ILL.—A new giant-size tool, capable of performing more simultaneously controlled motions than any other machine now in existence, is the first universal spar milling machine controlled by an electronic tracer system. The 90-ton machine is one of 18 being built for the U. S. Air Force Air Materiel Command by Onsrud Machine Works Inc. The tracer control system, developed by GE, enables one to twelve different feed motions at the same time.

The 84-ft machine can mill spar beams and parts up to 60 ft long. A gantry-type carriage houses four cutter motors that together develop over 320 hp. The machine has 167 control stations, 24 major light signals, 38 electric motors, and 36 safety control limit switches.

Four milling heads on the machine can be operated at one time, singly, or in any combination. Speeds, feeds and motions are in-

dividually controlled for each milling head and a total of 12 different movements or feeds is available, in addition to longitudinal feed. Longitudinal feeds of the cutter heads under full load are from zero to 340 in. per minute.

Each of the 12 tracer control systems employs a selsyn-type one-dimension tracer to direct a single machine feed. The control provides simultaneous rise and fall, transverse, and twist motions.

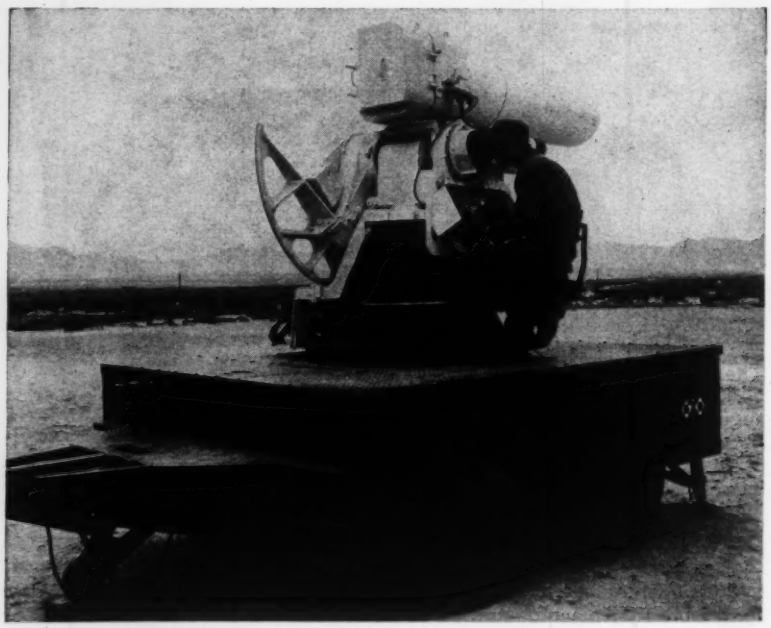
On the linear feed motions, each 400-cycle selsyn makes one revolution for each ½-in. of vertical follower motion. A corresponding selsyn is connected to rotate in relation to the follower which traces the configuration of linear templates mounted parallel to the working surface near the base of the machine.

In setting up the machine, careful mechanical adjustments are required to bring the follower head and the cutting head into exact correspondence. With the selsyn system, this is an electrical adjustment made by the operator turning a differential selsyn at the control station.

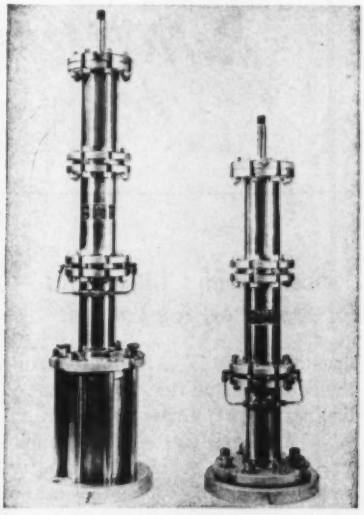
Four spindles, each with three available motions, are controlled by tracers. Two spindles are mounted vertically and two horizontally.

As the carriage moves along the machine at a selected speed, the follower heads move along the templates at the same rate. There is one follower for each of the 12 controlled motions.

Test results indicate that the new machine is capable of providing repeat cuts to accuracies of 0.002-in. at production rates as high as 300 in. per minute carriage feed and 30 in. per minute head feed. It was found that a 1-in. depth of cut 7 in. wide on rise and fall with changing transverse and twist motions can be made.



MISSILE MONITOR is this new telescopic tracker capable of following test missiles and similar flying objects up to 300 mi distant. Developed at the Army Signal Corps Laboratories, Fort Monmouth, N. J., the instrument includes a 400-lb lens of 160-in. focal length and automatic cameras. A main camera records flight of the subject and time. An auxiliary camera records direction and altitude of the subject. Manual positioning is accomplished by an operator using a steel sphere which rotates in a rocket and moves the instrument in horizontal and vertical planes. The tracker can be remotely controlled, which enables its use in danger areas.



DYNAMIC SHOCK-TESTING instruments, no larger than a golf bag, accurately simulate shock experienced by equipment in actual use. The Hyge Actuator, manufactured by the Rochester Div. of Consolidated Electrodynamics Corp., can apply widely varying forces for controlled periods of time. A 26-in. high actuator is capable of a 12,000-lb thrust. The instrument is essentially a piston in a cylinder, subjected to differential pressures on its two faces. Only two moving parts are the piston and a floating seal.

Products Simplified for Users Seen Complicating Manufacture

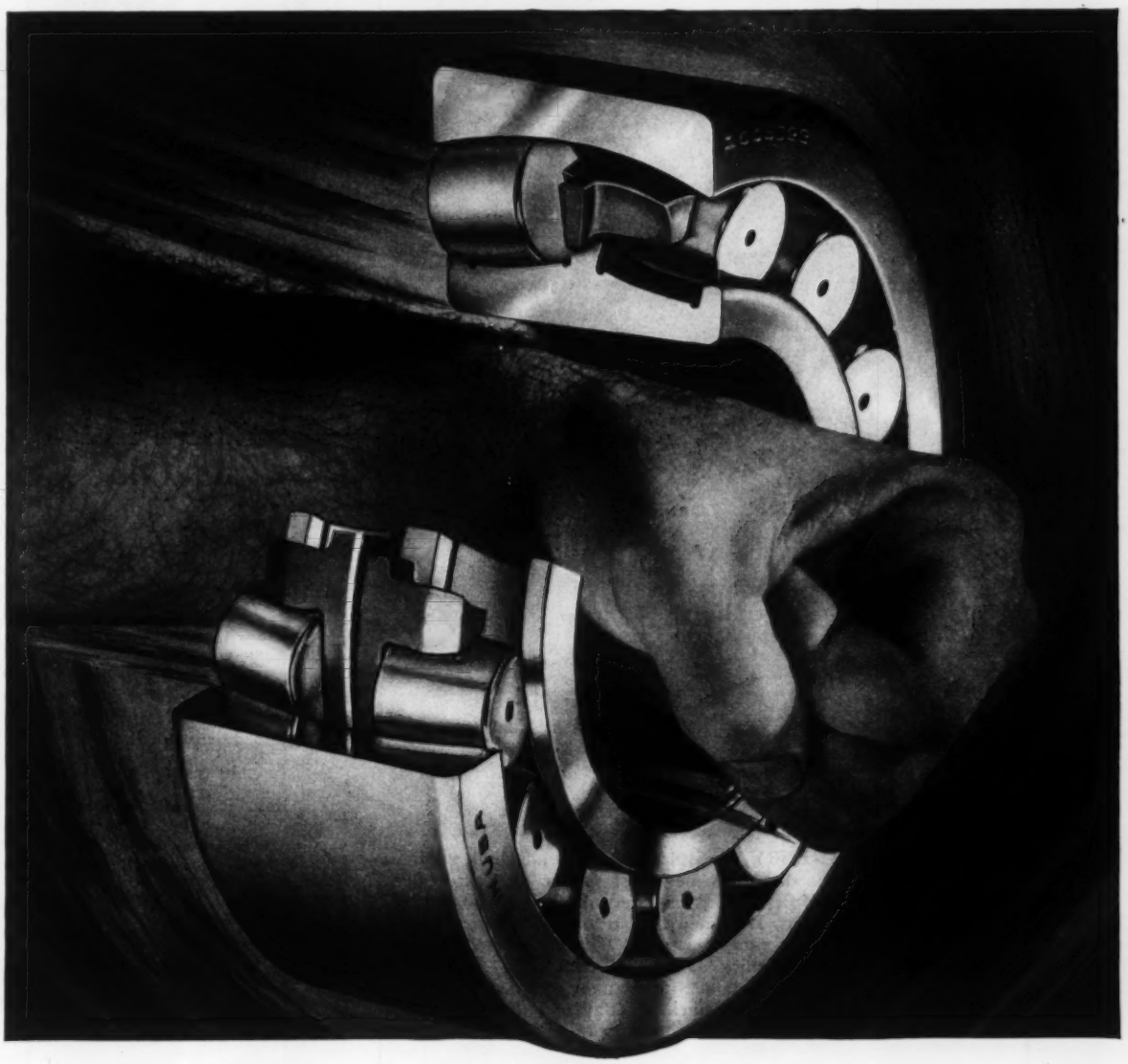
NEW YORK, N. Y. — "Complification" was the word coined recently by R. C. Graves, sales vice president of Federal Pacific Electric Co., to identify a kind of product simplification which actually involves increased manufacturing complications to the benefit of the eventual product user.

He noted that the model A car

Front Cover

All cams, regardless of their form or shape, are designed to provide a specified displacement within practical ranges of follower velocity and acceleration—a fact which cover artist George Farnsworth has used as a theme. "Scotty" Cram's article on Page 92 discusses some of the practical aspects of cam design and gives answers to some common problems.

TORRINGTON *SPHERICAL ROLLER* BEARINGS



This bearing can take thrust, too!

Design is the secret. TORRINGTON Spherical Roller Bearings are made with an integral center flange on the inner race. This assures *positive radial stability and accurate positioning of rollers* wherever high radial load and heavy thrust are encountered under conditions of misalignment.

From crushers to cranes, power shovels to pulverizers, you get long, maintenance-free operation, better performance in your equipment, more value from your bearing dollar when you specify these rugged dependable bearings.

Prove to yourself that TORRINGTON design does make a difference. Next time specify TORRINGTON Spherical Roller Bearings. They're available with either straight or tapered bore, for shaft or adapter mounting.

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South Bend 21, Ind. • Torrington, Conn.

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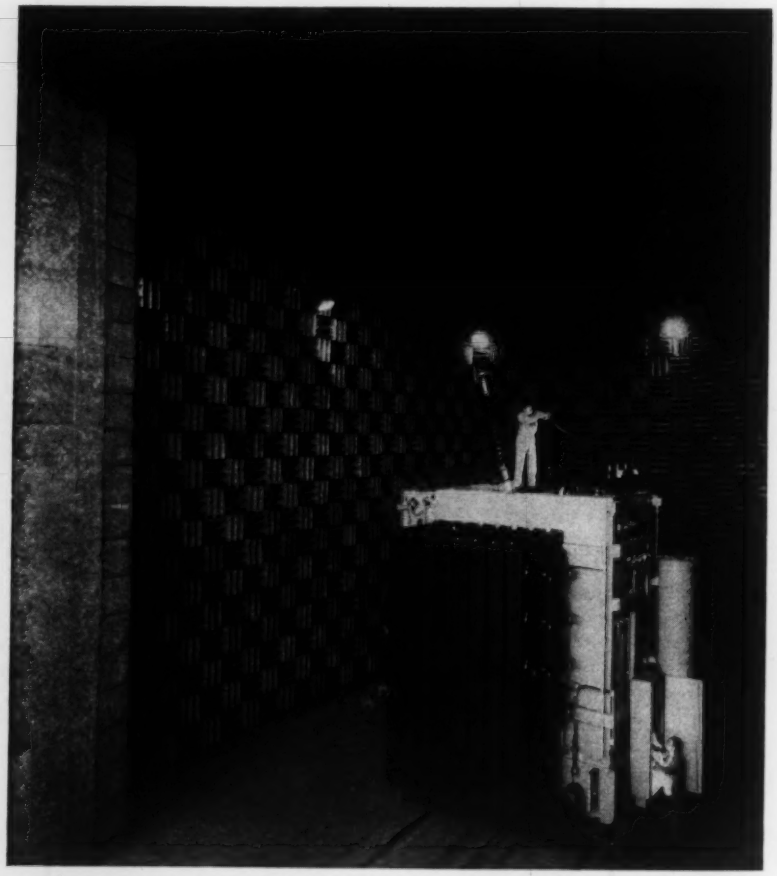
90th ANNIVERSARY

TORRINGTON BEARINGS

Spherical Roller • Tapered Roller • Cylindrical Roller Needle • Ball • Needle Rollers

Circle 507 on page 19



ELECTRICAL SOUND AND FURY are isolated by this anechoic vault in the Westinghouse transformer division's new test center at Sharon, Pa. Sound measurements are made on transformers rated more than 500,000 kva and weighing more than 400 tons. Designed for an ambient noise level of less than 30 decibels, the anechoic vault measures 70 ft long by 55 ft wide by 60 ft high; has walls nearly 5 ft thick. Each wall contains 12 in. of concrete, a layer of galvanized sheet steel, a 2-in. blanket of glass fiber in a 9-in. air space, and fiberglass wedges 3 ft thick. The layer of steel shields the room to permit radio-influence measurements on large units.

was simple to make but that modern cars, far more complicated to make, are simplified for drivers and passengers. "You can see the same trend in almost all products," Mr. Graves said. "Just look in any shop window and you must be convinced. From accordions to zippers, the trend seems to be away from simplification to complification.

"Simplification does not mean eliminating a feature here or there. It does not mean doing away with a given number of nuts and bolts. It does not mean making one item do the work of several.

"True simplification is to the manufacturer a reflection . . . of user simplification and user gratification. And this applies equally to consumer products and industrial products."

Mr. Graves said that complification means "the addition of product features, complicating the manufacturing process, but simplifying the product from the user's point of view. Complification is not the antithesis of simplification —it is just another form of the same thing."

Mr. Graves outlined consideration in the redesign of certain new electrical equipment. He noted that simplification was an objective in

Topics

Elimination of contrails — the streaks left in the sky by jet aircraft—is the subject of a three-year study by Cornell Aeronautical Laboratory. These vapor trails often stretch 100 miles behind a plane that otherwise would not be detectable.

• • •

Two-tone power mowers will grace many lawns next year, according to exhibitors at the recent National Hardware Show. Buyers who want a sportier model mower will be able to choose from combinations of red and cream, blue and gray and silver and orange.

• • •

Electronic refrigerators will be available in five years, according to a prediction by RCA.

• • •

Portable electric typewriters will make their debut in a couple of months. Smith-Corona, first to place such a machine on the market, has produced a model weighing around 18 lb, about 5 lb more than its manually operated cousin. Electrification of a few of the machine's controls had to be sacrificed to preserve compactness.

• • •

Latest reports on Ford's long-awaited Model E indicate that it will make its appearance late next year, as a 1958 model.

• • •

Penny-matching robot won 5218 times and lost only 4577 times at Bell Telephone Laboratories, beating 10 billion to one odds against getting such a large lead by chance. Winning money from nonelectronic brains, however, is merely an avocation of the device, which was developed as a forerunner to computers that might be able to adjust to changing environments. Such a computer would be useful in a telephone central office to measure traffic and adjust its apparatus accordingly.

• • •

The three-billionth ton of steel made in the United States was produced this year, according to the American Iron and Steel Institute. The billionth ton was processed around 1927. Thus, in the nearly 100 years since the beginning of bessemer steelmaking, about one-third of total production occurred during the first 70 years and two-thirds during the last 30 years.

News about

B.F.Goodrich Chemical *raw materials*

PLUG VALVE *of Geon for handling corrosive fluids demonstrates molding of complicated shapes with integral threads. At the bearing surfaces Geon is molded to another plastic.*

LOOK WHAT THEY'RE MOLDING IN GEON RIGID VINYL...

All parts shown made by Tube Turns Plastics, Inc.

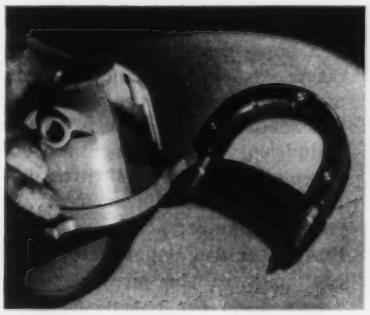
Geon polyvinyl chloride rigid compounds are recognized as outstanding materials for piping and fittings. Geon offers high impact and tensile strength, and superior resistance to oils, acids, alkalis, and most chemicals.

These same rigid compounds are being molded into many complicated shapes and parts in addition to piping components. Geon can be used in designs utilizing very thin sidewalls as well as heavy sections. Holes, studs, and threads can be made integrally. Parts weighing several pounds can be molded in one shot.

Despite design complexity, check Geon for strong, light, corrosion-resistant parts. For booklet on properties of rigid Geon compounds 8700A and 8750, write Dept. DO-6, B. F. Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ont.

B.F.Goodrich Chemical Company
a division of The B.F.Goodrich Company

BIG FELLOWS *include piping tee and motor housing, requiring heavy cross section, chemical inertness, dimensional stability. By contrast, molding for automobile dashboard has thin section, large projected area.*



ELECTRICAL PARTS *include fractional horsepower motor housing which reduces appliance weight, and hanger band for transformer with Geon molded around metal bolt. Geon has excellent dielectric properties.*

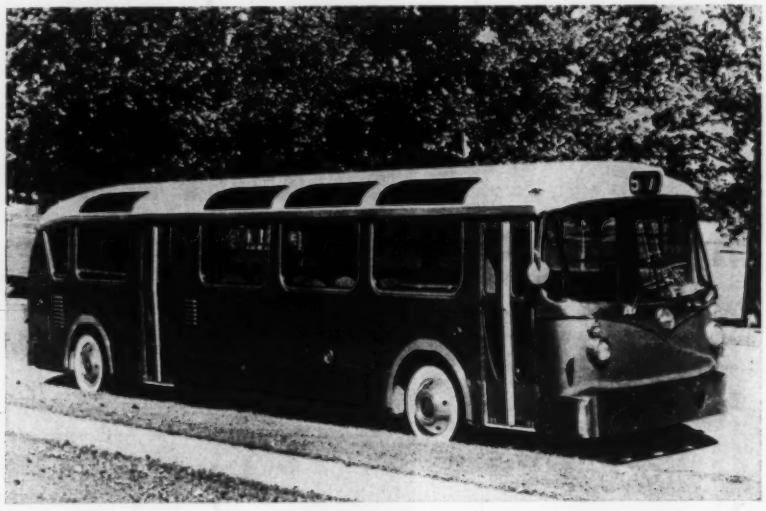
AUTO HORN *trumpet shows complicated contours possible in rigid Geon. Note very thin walls obtained in this high-impact material. Photos courtesy Tube Turns Plastics, Inc., Louisville, Ky.*

B.F.Goodrich **GEON polyvinyl materials • HYCAR American rubber and latex • GOOD-RITE chemicals and plasticizers • HARMON colors**

Circle 508 on page 19

distribution and merchandising as well as design and manufacturing. He emphasized that the requirements of the user must govern simplification at any stage of engineering or sales.

"When you decide that 'product simplification' is the solution to your manufacturing, marketing, or profitability problems, look first at the user's side of the coin. If you please him, you stand to gain enormously."



PICTURE WINDOWS IN TRANSIT BUSSES are forecast in this design of the "Bus of Tomorrow" by Mack Trucks Inc. The experimental model for city routes has wrap-around windshield and 60-in. side windows, the largest on busses of U. S. manufacture. Seats are mounted on single pedestals which carry concealed lights with pink lenses to eliminate shadows. Seats in the rear form a lounge accented by upholstery different from the other seats and an edge-lighted mural. Two aerials project from the roof. One can connect to an entertainment radio; the other is for the driver's radio-telephone.

Electronic Typewriter "Reads" Forms, Tabulates Automatically

NEW YORK, N. Y.—For the first time, electronics have been applied to the ordinary office typewriter and the result is a machine that "reads" prepared forms and automatically traverses without the presetting of mechanical tab stops. The electric typewriter with electronic tabulation was announced recently by the Electric Typewriter Div. of International Business Machines Corp.

Conventional machines require that tabular stops be set for each new form before the tab key can be used to position the carriage properly for each fill-in area. The electronic "reading" feature of the new IBM typewriter eliminates these adjustments no matter how many different types of forms are placed in the machine.

Vertical lines printed on a business form with electrically-conductive ink make the form sensitive to electrical impulses. These conductive lines, in effect, program the typewriter. When the tab key on the keyboard is depressed, a sensing unit close to the paper "reads" the form and automatically positions the typewriter carriage at successive typing points.

The "reading" unit is made operative by depressing an "electronic tab" lever on the front of the machine. If nonsensitized forms must be used, a flick of this same lever returns the machine to the conventional manual tab setting condition.

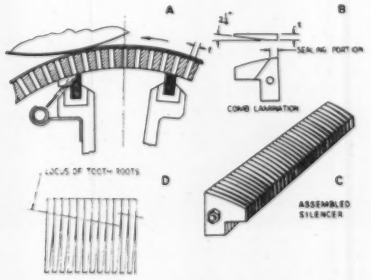
The electronic unit is mounted beneath the keyboard in a case approximately 3 by 6 in. in size.

Comb-like Plastic Packing Cuts Noise in Paper Mill

PHILADELPHIA, PA.—Intense noise produced by the suction rolls in a papermaking machine has been eliminated by a silencer built up of staggered plastic wedges which "scramble" the siren effect in the former design. Engineers at Scott Paper Co. have produced the new silencer with laminated plastic supplied by the Synthane Corp.

A paper machine suction roll extracts water from newly-formed wet paper web and carrying felts. The suction roll is a large, rotating cylindrical shell having thousands of small holes drilled through it. Inside the shell is a stationary vacuum chamber which applies suction to the wet paper web through the holes in the shell. Water is drawn from the paper and carrying felt into the shell holes as they pass over the vacuum chamber.

The noise is caused by the rapid re-entry of air into the partially evacuated shell holes as the holes leave the suction area. A damped oscillating pressure wave is created by each hole as it "breaks" over the packing on the off-going side of the vacuum chamber. With literally thousands of holes breaking per second, the noise produced



Operation and features of a paper machine silencer. As each row of shell holes leaves suction area, center line of *A*, the velocity of the air re-entering the evacuated shell hole is sharply reduced by the very small openings at the roots of the comb teeth. The wedge shape of the comb lamination *B* provides the narrow opening which exposes the hole gradually to atmospheric pressure, thus eliminating a sudden inrush of air and the resultant noise. The assembled silencer is shown at *C*. View *D* shows how the wedge-like openings are staggered.

NEW DEPARTURE BALL BEARINGS CUT COSTS IN CONVEYOR SYSTEMS

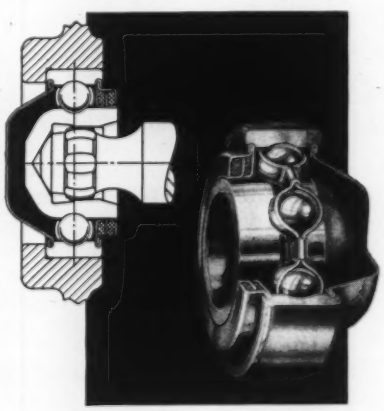
New Departure sealed and lubricated-for-life conveyor bearings have demonstrated their economy and dependability for many years in installations varying from sand and gravel plants to huge dam-construction projects.

These bearings do away with lubricating fittings, with grease piping, springs or adjusting devices and other miscellaneous items. Periodical greasing is eliminated with consequent important savings in labor and lubricant costs.

New Departure Type CB 504 bearings are unique in that they utilize short, easily removed stub shafts which allow a self-aligning motion in the bearing bore, yet at the same time prevent the inner ring from turning.

Carriers developed around these few parts are simple in design and remarkably easy to erect in the field.

For information on New Departure conveyor bearings, use the coupon below. Or call for New Departure's engineering service—ready to add its specialized experience to yours to help you build the best products possible. New Departure, Division of General Motors, Bristol, Connecticut.



Unique shape of the inner ring of Type CB 504, together with hexagonal curved surfaces on end of stub shaft, provides positive, self-aligning union between roll and supporting bracket.

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Ball Bearings Make Good Products Better

New Departure Division
General Motors Corp.
Bristol, Connecticut

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NEW DEPARTURE
BALL BEARINGS
GM GENERAL MOTORS
NOTHING ROLLS LIKE A BALL

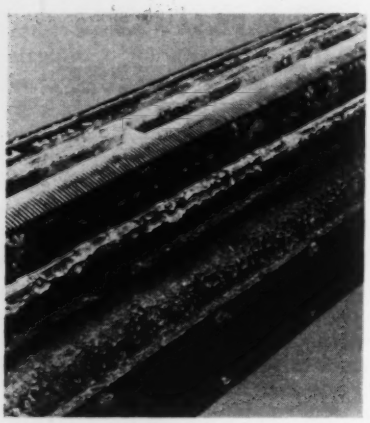
Circle 509 on page 19

XUM

is a siren-like scream of high intensity.

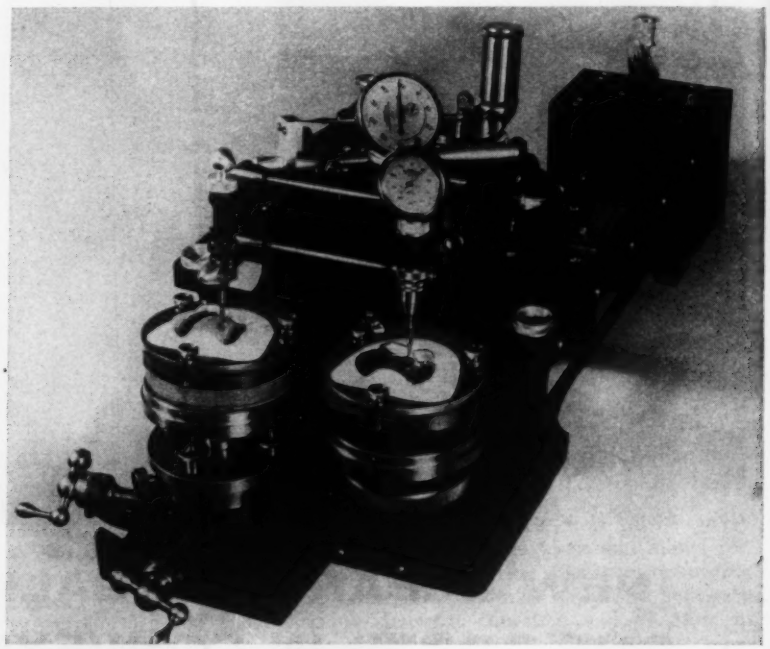
Initially it was found that the pattern of the holes in the roll shell could be designed so that the sound pressure waves from one hole could be largely cancelled by the wave from the next hole. A significant noise reduction was obtained in this manner.

An even greater noise reduction was required, however. To achieve this, a special, comb-like packing was designed to replace the plain packing on the off-going side of the vacuum chamber. Each hole in the rotating shell passes over one of the wedge-like openings between the teeth of the comb. The partially evacuated hole, therefore, is not suddenly exposed to air at atmospheric pressure. Since the magnitude of the sound pressure wave created at each hole is proportional to the rate of air flow into it, the comb silencer effectively reduced the noise of the suction roll to a level which was below the background level prevailing in the area.



Suction box from a paper machine shows a "comb silencer" in operating position.

The silencer is formed from a stack of shaped laminations bolted together to form a semirigid packing strip. This construction affords the further advantage of allowing the wedge-like openings between the teeth to be staggered, thereby producing additional noise reduction through "phase cancellation" of the hole pulses. Necessary properties of the plastic are wear resistance and low coefficient of friction lubricated with water.



DUPLICATE DENTURES are measured on this new comparator, developed at the National Bureau of Standards, to evaluate denture techniques and materials. A pantograph type of comparator, the instrument measures the surface contours of two dental impressions and indicates differences to an accuracy of ±0.002-in. or better. It can be used on both hard and soft materails. An electronic device turns off a light to indicate contact of the guide pointer. Elevation differences between guide and indicator pointers are read on the dial gage. Scribing head at left can plot differences on charts.

Welded Graphite, Improved Basic Materials Announced

PARMA, O. — Two important achievements in basic materials were announced recently at the dedication of Union Carbide's new research laboratories, managed by its National Carbon Div.

Dr. Robert G. Breckenridge, director of the laboratories, said that National Carbon scientists have discovered for the first time in history how to "weld" pieces of graphite together. He also announced that the largest single crystals of cadmium sulfide ever reported have been "grown" in the new laboratories.

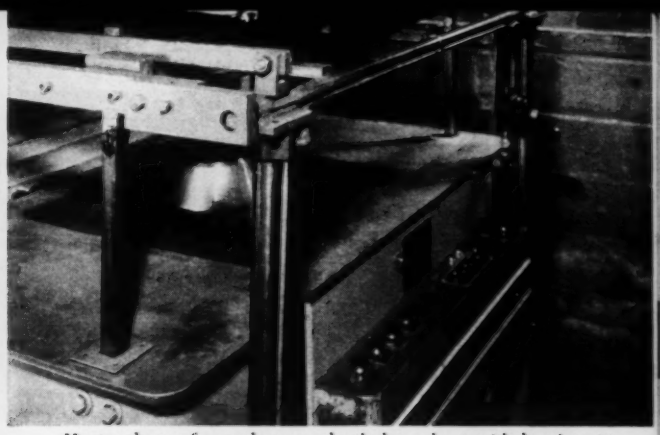
A light-sensitive material, cadmium sulfide can be used in photocells, solar batteries, and as a light-producing phosphorescent material when properly activated. It has been found, Dr. Breckenridge said, that the photoconducting properties of single crystals are superior to those of polycrystalline film. Laboratory crystals $\frac{3}{8}$-in. in diameter and several inches long have been produced by new techniques.

Heated in special crucibles under high pressure to prevent vaporization, liquid cadmium sulfide is allowed to cool slowly. As it cools, a single crystal emerges, and takes its shape and size from the crucible.

The ability to weld graphite, Dr. Breckenridge said, suggests the use of prefabricated sheets and panels of graphite for the assembly of nuclear reactor moderators which now must be built of graphite blocks.

Key to the new welding process is the heating of graphite in an atmosphere of an inert gas with the application of high pressure. The pressure prevents vaporization of the graphite which would

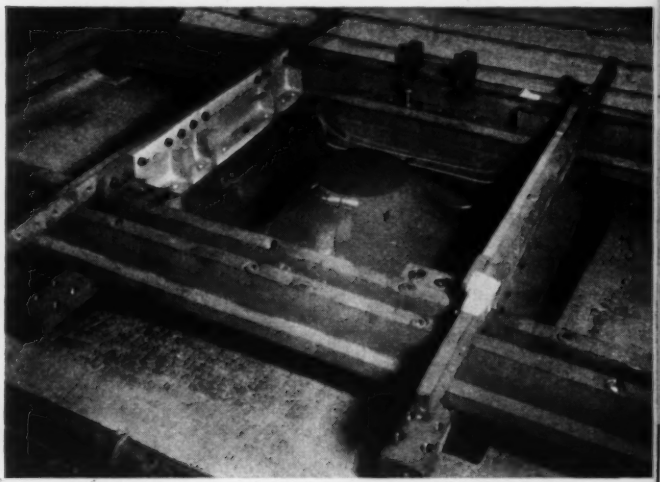
High gloss is evident on this polyethylene sheet being placed in clamping frame just prior to vacuum-forming.



Heater drawn forward over polyethylene sheet with bowl mold in position. Low mold cost is one advantage of the vacuum-forming process.

Partial list of properties of BAKELITE Polyethylene DFD-4030, based on laboratory tests:

Specific Gravity (D792-50 Method A)	0.92
Melt Index (D1238-52T)	1.7-2.4
Tensile Strength (D412-51T), psi	1800
Per Cent Elongation (D412-51T)	550
Brittle Temperature (D746-55T), 80% non-failure, deg. C.	-80
Stiffness Modulus (Torsion) at 23 deg. C. (D1043-51)	22,000
Durometer Hardness (D676-49T)	40 at 75 deg. F., 28 at 140 deg. F.
Coloring Properties	Unlimited



Heated polyethylene sheet drapes over mold before vacuum is applied. DFD-4030 is readily deep-drawn to large-size sections.

Now . . . Design for

The performance features of polyethylene, the production economy of vacuum-forming

Here is a new development from the laboratories of Bakelite Company, major supplier of the leading extrusion plastics for vacuum-forming. BAKELITE Brand Polyethylene DFD-4030 is especially compounded for the process. Your product can now enjoy all the well-known advantages of polyethylene in addition to fast, economical fabrication.

Vacuum-forming has gained wide acceptance because of its speed and low cost, *particularly for large-size sections.* The simplicity of the process is evident from the pictures on this page, taken at Bakelite Company's extrusion laboratory, where BAKELITE Polyethylene DFD-4030 is carefully evaluated for optimum performance under vacuum-forming.

Now, the many advantages of polyethylene—light weight, chemical resistance, dielectric strength, color—are available to products vacuum-formed from DFD-4030. The table above gives some of its performance properties. For more details, consult your plastics fabricator or write Dept. VC-103.

BAKELITE BRAND PLASTICS

BAKELITE COMPANY, *A Division of Union Carbide and Carbon Corporation* UCC 30 East 42nd Street, New York 17, N. Y.

In Canada: Bakelite Company, Division of Union Carbide Canada Limited, Belleville, Ontario

The term BAKELITE and the Trefoil Symbol are registered trade-marks of UCC.

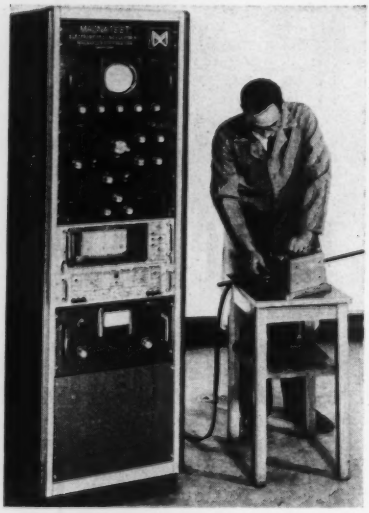
Circle 510 on page 19

occur if heat alone were used.

The technique has led to the production of new forms of graphite which have a much higher degree of crystalline perfection than any artificial graphite obtainable up to now, according to Dr. Breckenridge.

A similar technique is used for a sort of continuous casting process, in which comparatively large pieces of graphite are formed from the liquid state. This graphite has a degree of crystalline perfection comparable with that of the best natural graphite.

Another form of graphite recently produced are very fine filaments, resembling whiskers, having diameters smaller than 0.0001-in. The filaments have exceptional tensile strength, perhaps as much as ten times that of normal carbon materials, and ability to withstand severe plastic distortion without breaking.

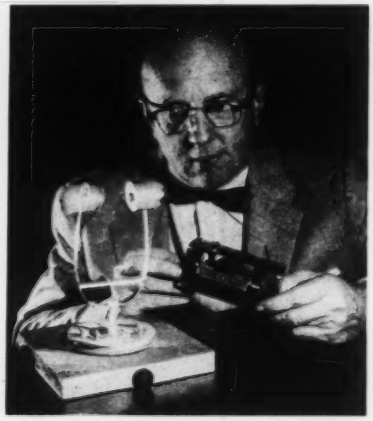


NONDESTRUCTIVE TESTER for nonmagnetic materials has been announced by the Magnaflux Corp. The Magnatest FW-400 inspection unit operates on rod, wire, tube and bar stock in sizes from 1/64 to 3 in. Materials inspected can be aluminum, brass, copper, tungsten, austenitic stainless steel and titanium. The unit locates seams, embrittled areas, diameter variations, voids and inclusions in materials moving at 150 to 300 fpm.

Vibrating Elements Are Heart of New Gyro

PITTSBURGH, PA.—A new type of gyroscope, believed to be the first practical commercial device of its kind, employs the vibrating mass of a tuning fork instead of a rotating mass as in conventional types. Called a vibragyro, the new device was developed by Westinghouse engineers K. A. Oplinger and George Douglas as a stabilizing element for missiles.

The vibragyro is based on a method of stabilization used by the common housefly and other two-winged insects. The fly is equipped with small organisms called "halteres" which, by vibrating rapidly,

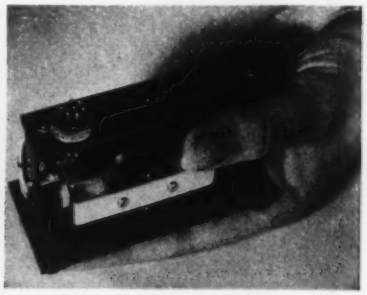


Vibragyro held by K. A. Oplinger operates like simple tuning fork.

govern its balance during flight.

Mr. Oplinger explained that a simple tuning fork can be used to demonstrate the basic principles of the vibragyro. If the fork is turned about a vertical axis, with the masses vibrating toward and away from the axis, gyroscopic forces are developed in the form of a couple which produces an oscillating torque about the input axis. This torque produces a small deflection whose amplitude is proportional to the rate of turn or input velocity.

In the Westinghouse vibragyro two masses are attached to the sides of a rigid rectangular frame having two heavy ends which might be compared to bases of a double tuning fork. This assembly is supported by two wires which also serve to isolate the vibrating forces from the base of the vibragyro. A small transducer is used to change the gyroscopic angular vibrations to an alternating electrical signal whose amplitude is proportional to the rate of turn.



Compact vibragyro is designed for control of missiles and aircraft.

Sensitivity of the vibragyro can be selected in the range 0.5 to 300 degrees per second. Advantages claimed are light weight, absence of bearings, small size, simplicity and ruggedness, long life, and short starting time.

Radio Receiver Provides Alert Warning Automatically

CAMDEN, N. J.—An electronically vigilant radio receiver that provides visual and audible warnings of air alerts is announced by the Communications Products Dept. of Radio Corp. of America. Operating unattended, the receiver automatically seeks and finds a Civil Defense Conelrad (control of electromagnetic radiation) frequency for radio coverage during an enemy attack.

Under Civil Defense procedures, commercial broadcast stations leave the air in the event of enemy air attack to prevent use of their radiated signals as location guideposts. The two Conelrad frequencies have been established for broadcast of instructions and news during such emergencies. The new RCA receiver provides a standard radio band as well as two Conelrad frequencies. The user can preset the Conelrad frequency assigned to his locality to provide automatic switch-over from stand-

ard-band operation.

Activation of the receiver can be accomplished by turning it on and tuning it to any standard-band station in the area. If operated with the speaker off, the receiver automatically switches on and seeks a Conelrad frequency with the transmission of an alert by the station. A green light glows on the instrument panel to advise that incoming broadcast signals are being received. At the conclusion of the emergency, the receiver automatically resumes reception from the broadcast station to which it was tuned. Visual warnings consist of a series of lights on the control panel which light up in accordance with changes in receiver operation.

Meetings

AND EXPOSITIONS

Nov. 12-16—

National Electrical Manufacturers Association. Annual Meeting to be held at the Traymore Hotel, Atlantic City, N. J. Further information is available from association headquarters, 155 E. 44th St., New York 17, N. Y.

Nov. 13-15—

Investment Casting Institute. Fourth Annual Meeting to be held at the Sheraton Cadillac Hotel, Detroit. In addition, a Vacuum Metals Symposium will be held Friday, November 16. Further information can be obtained from ICI headquarters, 27 E. Monroe, Chicago 3, Ill.

Nov. 14-17—

Society of Naval Architects and Marine Engineers. Sixty-fourth Annual Meeting to be held at the Waldorf-Astoria Hotel, New York. Further data can be obtained from society headquarters, 74 Trinity Place, New York 6, N. Y.

Nov. 15-16—

Operations Research Society of America. Tenth National Meeting

(*Continued on Page* 22)

The answer to your current project ...or your next one... may be easier with one of these Special-Application Instruments

If you think Stromberg-Carlson makes telephones only for office or home conversation, you should know how many instruments we offer for specialized jobs.

Shown above are just a handful, developed for somebody's special project.

Suspended-type 'phones, great space-savers; used either in dial or manual service.

Remote-control instruments, such as we make to work with dictating machines. "*Press-to-talk*," "*Press-to-receive*" and "*Press-to-control*" handsets, very popular in two-way radio applications. "*1574*" telephones, with a special key for transferring calls (or other functions) from one line to another.

NEW CATALOGUE, with complete description of all special-project instruments, sent you on request. Or for a specific problem, just write

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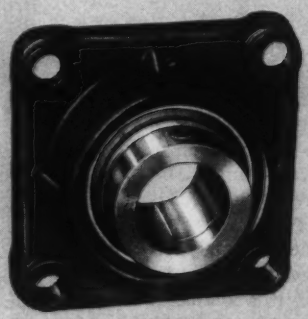
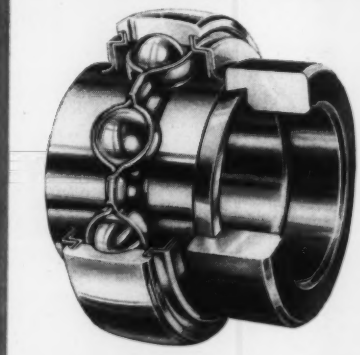
Circle 511 on page 19

NEW! Fafnir Wide Inner Ring Ball Bearings with PLYA-SEALS . . . *contact type*

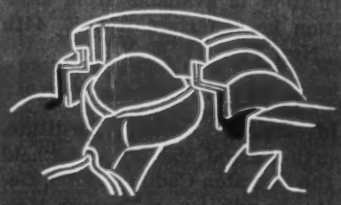
A most important feature . . . *on slow-speed applications where service conditions are excessively dirty and moist*



RCJ Flange Cartridges
(Standard Series)



RAK, RAS Pillow Blocks
(Standard Series)



Plya-Seal Construction
— for wide inner ring ball bearings. A synthetic rubber, contact-type seal located between two "dished" steel plates for extra rugged support.

With the addition of this version of PLYA-SEALS to the Fafnir line of wide inner ring ball bearings, you can be more selective in the type of sealed bearing you specify and install. Where service at slow to moderate speeds demands most effective protection against contaminants, especially air-borne dust, dirt and grit, the Plya-Seal type offers the advantages of contact seals, tested and proven by years of service.

Plya-Seal Wide Inner Ring Bearings are optional on the standard series Pillow Blocks and Flange Cartridges. They are dimensionally interchangeable with the Fafnir Mechani-Seal. Flared lip and clearance between inner supporting seal member and inner ring O.D. keeps seal from pushing in. Plya-Seals do not absorb contaminants, thus their surface won't glaze and lose its efficiency. *Fafnir Wide Inner Ring Bearings equipped with Plya-Seals are relubricatable!*

Here's an opportunity to improve operations, reduce servicing, eliminate loss of lubricant, provide the most effective protection from contaminants. For new Bulletin on Plya-Seal Wide Inner Ring Ball Bearings, ask your Authorized Fafnir Distributor or write The Fafnir Bearing Co., New Britain, Conn.

FAFNIR
BALL BEARINGS
MOST COMPLETE LINE IN AMERICA

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Reader Information Service

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USE A YELLOW CARD *for More Information . . .*

CIRCLE ITEM NUMBERS—Throughout the magazine, each advertisement carries an Item Number for use in requesting further information. All product descriptions, announcements and Helpful Literature items are also numbered, and for greater convenience are indexed below by Item Numbers.

EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

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BY ITEM NUMBERS

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412	437	462	487	512	537	562	587	612	637	662	687	712	737	762
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415	440	465	490	515	540	565	590	615	640	665	690	715	740	765
416	441	466	491	516	541	566	591	616	641	666	691	716	741	766
417	442	467	492	517	542	567	592	617	642	667	692	717	742	767
418	443	468	493	518	543	568	593	618	643	668	693	718	743	768
419	444	469	494	519	544	569	594	619	644	669	694	719	744	769
420	445	470	495	520	545	570	595	620	645	670	695	720	745	770
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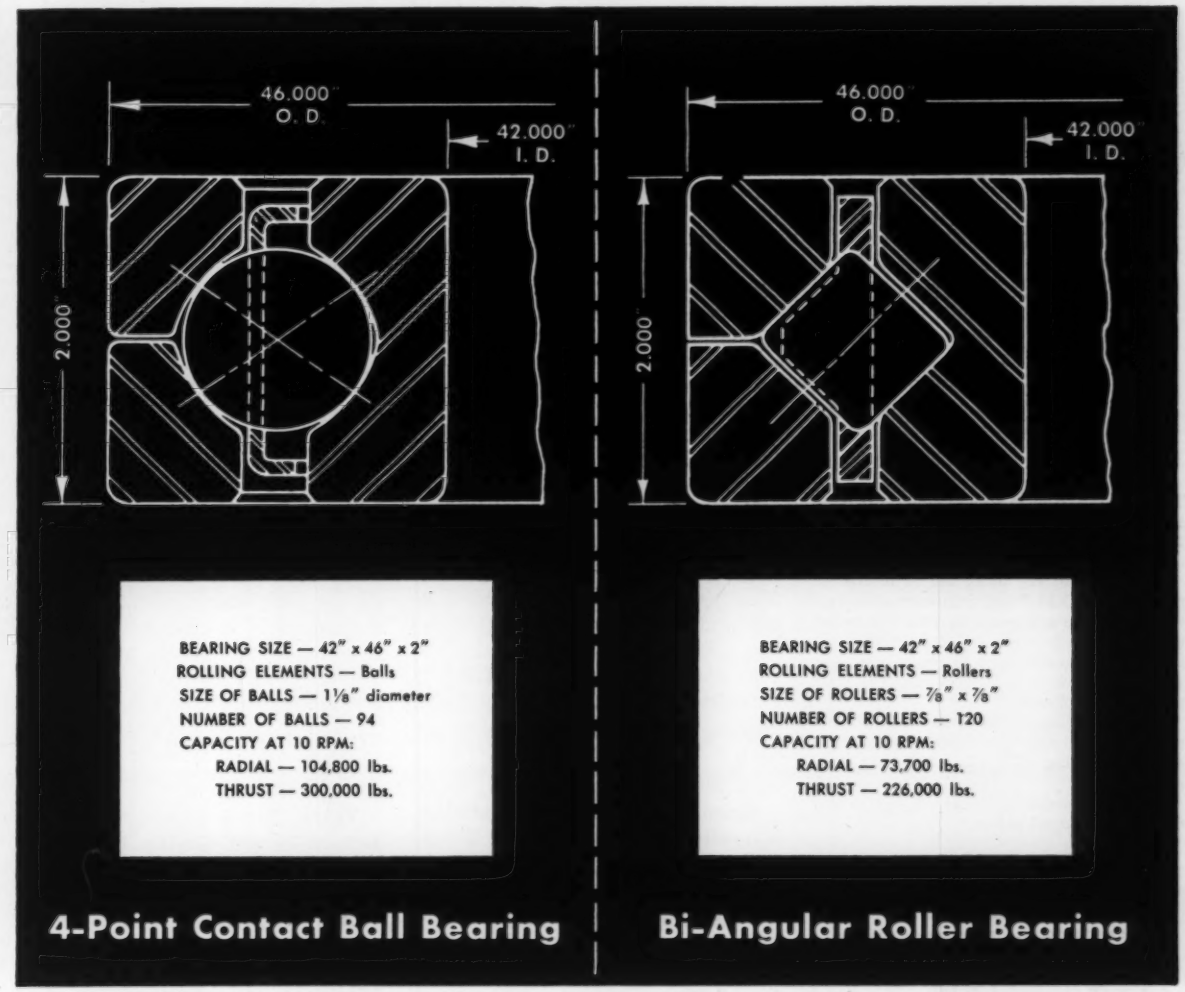
46.000" O. D.
42.000" I. D.
2.000"
BEARING SIZE — 42" x 46" x 2"
ROLLING ELEMENTS — Balls
SIZE OF BALLS — 1⅛" diameter
NUMBER OF BALLS — 94
CAPACITY AT 10 RPM:
RADIAL — 104,800 lbs.
THRUST — 300,000 lbs.
4-Point Contact Ball Bearing
46.000" O. D.
42.000" I. D.
2.000"
BEARING SIZE — 42" x 46" x 2"
ROLLING ELEMENTS — Rollers
SIZE OF ROLLERS — ⅞" x ⅞"
NUMBER OF ROLLERS — 120
CAPACITY AT 10 RPM:
RADIAL — 73,700 lbs.
THRUST — 226,000 lbs.
Bi-Angular Roller Bearing

SURE we make both, but we recommend only one

Yes, Kaydon manufactures both — 4-point contact ball and bi-angular roller bearings in the same diameters and widths. BUT—we would in almost every instance recommend the former. Why? Because our field application reports consistently prove that the 4-point contact ball bearings are better for most applications than the lower capacity bi-angulars *(See capacity figures in drawings above.)*

Another important difference between the two bearings is that the 4-point contact ball bearing *is not limited to low speeds,* whereas the bi-angular normally should not be used above 10 rpm and usually is suitable only for oscillation. Then, too, the torque in the 4-point contact ball bearings is generally much lower.

Kaydon's unbiased recommendations result from years of bearing design, application and manufacturing experience with *all types* of ball and roller bearings up to 124" in diameter. So, why not contact Kaydon first?

K-563

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

All types of ball and roller bearings — 4" inside diameter to 124" outside diameter . . . Taper Roller • Roller Thrust • Roller Radial • Bi-Angular Roller • Spherical Roller • Needle Roller • Ball Radial • Ball Thrust Bearings

The best way to solve your cylinder problems is to discuss the problems with your O-M Field Representative in your own plant or office.

Whether you are using air or hydraulic power, your O-M Field Representative can be of valuable assistance to you. His broad experience with cylinder applications and installations qualify him to recommend the air or hydraulic cylinder best suited to your particular application.

Ortman-Miller offers you the full facilities and resourcefulness of its Field Organization and Engineering Staff without cost or obligation.

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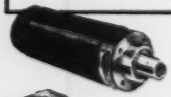
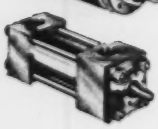
HACKETT BROTHERS, INC. North Manchester, Indiana
KNOX, INC. East Walpole, Mass.
H. D. MacRAE Rochester, New York
THE MERCER COMPANY Milwaukee, Wisconsin
WALTER NORRIS ENGR. CO. Chicago, Illinois
PAR INDUSTRIAL SALES LTD. Toronto, Canada
PNEUMATIC ENGR. CO. Hartford, Conn.
P. W. RICE Cleveland, Ohio
THE RODEN COMPANY Cranford, New Jersey
H. U. ROGNESS, INC. Minneapolis, Minnesota
THE RUCKER COMPANY Oakland, California
ROBERT TAYLOR & SONS Salt Lake City, Utah
WOMACK MACHINE & SUPPLY CO. Dallas, Texas
ZOPF ENGINEERING CO. Kansas City, Missouri





O-M tie-rodless (Round Line) air and hydraulic cylinders — rated to 500 psi Air; to 1500 psi Hydraulic.

Series TH (Square Line) hydraulic cylinders — rated to 2000 psi.

Both lines of cylinders are available in complete range of sizes (1½" to 8" bores) with standard or oversize rods.

ORTMAN-MILLER MACHINE CO.
7 143rd Street, Hammond, Indiana

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☐ Send Bulletin 101A (Round Line)

Name_____ Position_____
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Engineering News Roundup

(*Continued from Page* 15)

to be held at the Hotel Mark Hopkins, San Francisco. Additional information can be obtained from Operations Research Office, Johns Hopkins University, 7100 Connecticut Ave., Chevy Chase 15, Md.

Nov. 25-30—

American Society of Mechanical Engineers. Annual Meeting to be held at Hotel Statler, New York. Further information is available from society headquarters, 29 W. 39th St., New York 18, N. Y.

Nov. 25-30—

22nd National Exposition of Power and Mechanical Engineering to be held at the Coliseum, New York, under the auspices of the American Society of Mechanical Engineers. Additional information can be obtained from exposition headquarters, 480 Lexington Ave., New York 17, N. Y.

Nov. 26-30—

Third International Automation Exposition to be held in the Trade Show Bldg., New York. Further information can be obtained from Richard Rimbach Associates, 845 Ridge Ave., Pittsburgh 12, Pa.

Dec. 9-12—

American Society of Agricultural Engineers winter meeting to be held at the Edgewater Beach Hotel, Chicago. Further information can be obtained from society headquarters, 420 Main St., St. Joseph, Mich.

Dec. 10-11—

Material Handling Institute Inc. Annual Meeting to be held at the Biltmore Hotel, New York. Further information can be obtained from institute headquarters, Suite 759, 1 Gateway Center, Pittsburgh 22, Pa.

Dec. 10-12—

1956 Eastern Joint Computer Conference to be held at the Hotel New Yorker. Sponsors are the Institute of Radio Engineers, American Institute of Electrical Engineers and the Association for Computing Machinery. Additional information is available from publicity chairman Albert J. Forman, Tele-Tech & Electronic Industries, 480 Lexington Ave., New York 17, N. Y.

Jan. 14-16—

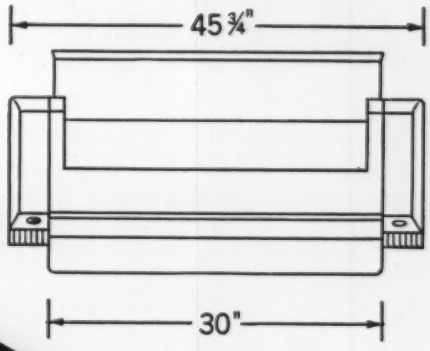
Third National Symposium on Reliability and Quality Control in Electronics to be held at the Hotel Statler, Washington, D. C. Sponsors are Institute of Radio Engineers, American Society for Quality Control, American Institute of Electrical Engineers and Radio-Electronic-Television Manufacturers Association. Further data are available from Mr. R. G. Murrell, Melpar Inc., Falls Church, Va.

It Never Fails . . .

"We've got to release the drawing today, so forget the little details; the checker will catch them."

"Mind checking these? The checker is loaded."

At Last! A Small Whiteprinter that Makes BIG Prints!



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NEW! BRUNING Copyflex Model 300!

Brings "Inside" Reproduction within the Means of the Smallest Engineering Firm or Department!
Now, with your low-cost, versatile Model 300, you can make high quality prints when you want them—rapidly, privately, and in any quantity. You can exercise complete control over valuable originals at all times.

Provides Large Companies an Economical Way to Supplement Main Reproduction Centers!
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Here it is! The compact, low-cost reproduction machine that offers all the versatility and big printing width of a large, expensive whiteprinter!

Just think—you can make sharp, black-on-white prints in seconds of a drawing or tracing up to 30 inches wide by any length. And anyone can operate the Model 300 after only brief instruction. One fingertip control turns the machine on or off and regulates its speed. Exposure and development are automatically synchronized.

The new Copyflex Model 300 is ideal for drafting rooms and offices because it can be operated anywhere without annoyance to personnel in the vicinity. It is clean, quiet, and odorless. No exhaust venting, plumbing, or accessory equipment required. It needs only a connection with a 115-volt AC outlet for operation.

If you're pressed by the boom in production for more and more engineering prints, the all-new Copyflex Model 300 is your answer! Its low initial cost combined with outstanding economy and convenience of operation and maintenance make it your soundest, low-cost investment of the year. Mail coupon today! You'll be glad you did!

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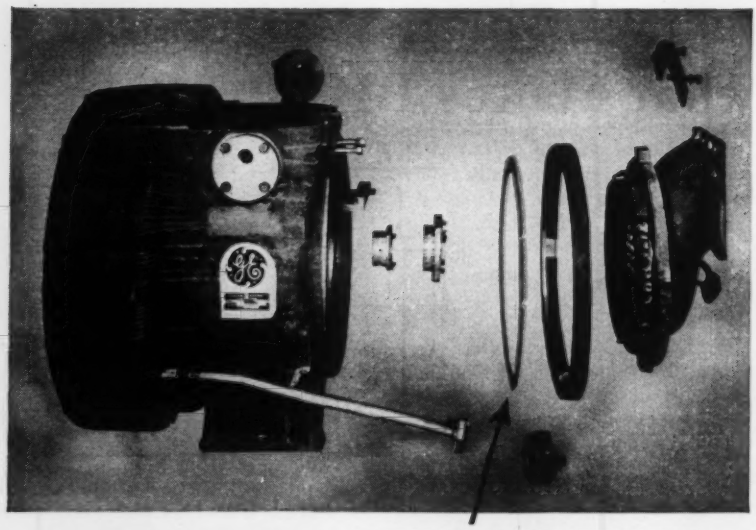


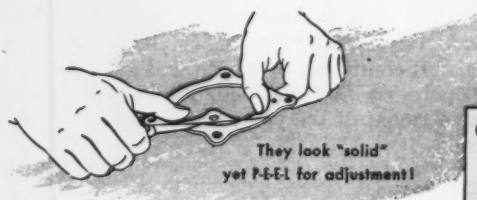
LAMINUM® adjustable SHIMS

cut assembly costs on turbo-supercharger for diesel engines

THIS is only one from thousands of laminated shim applications throughout all industry. Yet the reason for using laminated shims and the gains resulting are typical. This shim sets the clearance between the nozzle and buckets on the General Electric RD3C turbo-supercharger. Shimming is essential because of the accumulation of tolerances. The laminated shim can be adjusted quickly merely by peeling—and after peeling is always precisely uniform in thickness from end to end and side to side. Peeling is far easier and faster than precision grinding which would prove quite costly on these extremely large shims.

Whenever you need shims, call the Laminated Shim Company *first*...for fast, complete service. We manufacture shims in aluminum, brass, steel—small as a fingernail and large enough for locomotives...laminated, spot-soldered or looseleaf. Produced to your own precise blueprint specifications.

For further information and free booklet telling all about laminated shims and how they're used, please write. No cost or obligation, of course. Write today!



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The name Laminum is registered with U. S. Patent Office

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LAMINATED SHIMS OF LAMINUM® AVAILABLE IN BRASS • STEEL • STAINLESS STEEL • ALUMINUM

MEN

OF MACHINES

Appointment of **Richard S. Hildreth** as assistant chief engineer has been announced by Michigan Tool Co., Detroit. Mr. Hildreth joined the company's engineering

Richard S. Hildreth

department in 1950 and was assistant chief tool engineer prior to his new appointment. He has held a variety of engineering and design positions in the machine tool and affiliated industries since he graduated from Wentworth Institute in 1938.

Albert J. Hanssen has been appointed chief engineer of Conoflow Corp., Philadelphia. He was previously chief engineer of the Climax Div. of Black, Sivalls & Bryson Inc.

B. M. Wolfframm has been elected vice president of Magnetic Research Corp., El Segundo, Calif. Before joining this company in 1954, Dr. Wolfframm served as a specialist in magnetic circuits and components at Wright-Patterson Air Force Base and as senior research engineer on magnetic amplifiers and related magnetic control equipment in the Electronics Section of North American Aviation Inc.

Circle 516 on page 19

Men of Machines

Marshall P. Wilder has joined Allen B. du Mont Laboratories Inc., Clifton, N. J., as staff engineer in charge of the company's storage tube development program.

E. Finley Carter has been appointed director of Stanford Research Institute, Menlo Park, Calif. He has also been named to the institute's board of directors. Before joining SRI in 1954 as manager of research operations, Mr. Carter had served in a variety of engineering positions with General Electric Co., United Research Corp. and Sylvania Electric Products Co.

Acoustica Associates Inc., Glenwood Landing, N. Y., has announced the appointment of **Donald R. Church** as chief engineer, **Morris Kenny** as project engineer of the company's long-range Air Force Missile System Development Program and **Martin A. Damast** as senior electronic engineer.

Twin Disc Clutch Co., Racine, Wis., has announced the promotion of **Edward C. Yokel** to chief engineer of the General Products Div. at Racine and **James B. Black** to chief engineer of the Hydraulic Div. in Rockford, Ill. Mr. Yokel joined the company in 1937, was transferred to the Hydraulic Div. the next year and was made assistant chief engineer in 1945. In

Edward C. Yokel

AN IMPORTANT

NEW CATALOG FOR YOUR FILES!

WINSMITH, Inc., 16 Elton Street
Springville, (Erie County), N. Y.

Gentlemen: Please send me a copy of Catalog 155 on the new Series "C" Speed Reducers.

NAME TITLE

COMPANY

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CITY ZONE STATE

WINSMITH CATALOG 155

DESCRIBING THE NEW

"C" SERIES SPEED REDUCERS

Between the covers of this new catalog, every design engineer and speed reducer user will find the answer to how they can select speed reducers of more compact dimensions to achieve required output.

With this newly designed "C" Series, Winsmith has succeeded in increasing horsepower and torque output, and increasing the ruggedness of the units *without increasing overall size*. In all, 108 models in single and double reduction are available within the range of .01 to 34 hp; in a ratio range of 5:1 to 4460:1 and in an output torque range of 142 in. lbs. to 34,767 in. lbs. The complete "C" Series plus a number of other popular models in the Winsmith line are catalogued for your working convenience.

FOR YOUR COPY OF CATALOG 155 FILL IN AND MAIL THE COUPON TODAY!

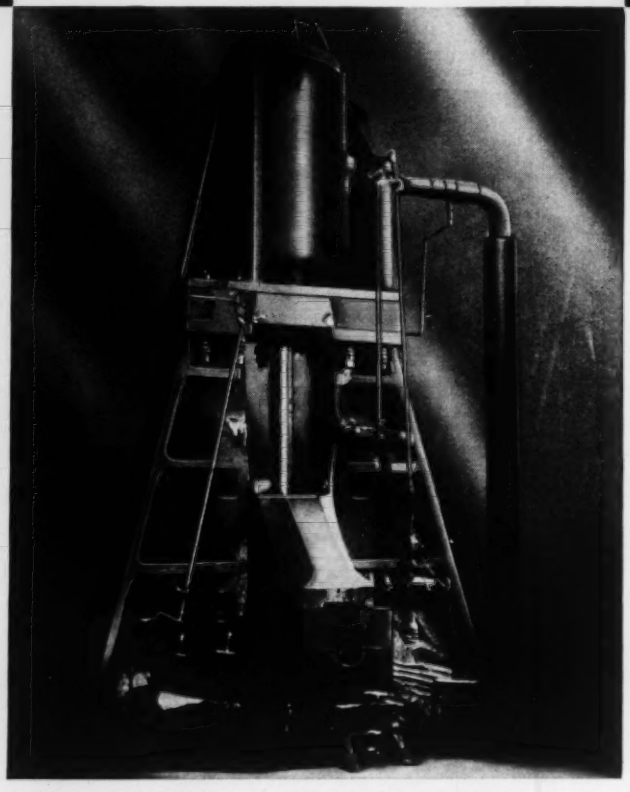
WINSMITH SPEED REDUCERS

...a single source for the most complete line of speed reducers within the range of 1/100 h.p. to 85 h.p. in ratios of 4.1:1 to 50,000:1

WINSMITH, INC.
16 Elton Street
Springville, (Erie County), N. Y.

PARK installs the world's largest

STEAM DROP HAMMER



TO CUT COSTS, IMPROVE QUALITY ON YOUR CLOSED-DIE FORGINGS

This 50,000 lb. steam drop hammer, the largest in the world, was especially designed and built for Park Drop Forge. Installed in the Fall of 1956, it is part of Park's continuing plant expansion plan to produce a complete range of the finest in steel closed-die forgings.

Park's facilities include a complete die sinking shop, modern specialized heat treating equipment and experienced metallurgical and engineering staffs.

A Park Sales Engineer will show you how Park die forgings can increase strength and safety—cut down size and machine time on your product requirements.

Die Forging Specialists Since 1907

THE PARK DROP FORGE CO.

773 EAST 79TH ST. • CLEVELAND 3, OHIO

CARBON, ALLOY AND STAINLESS STEEL CLOSED-DIE FORGINGS FROM 4 LBS. TO 5000 LBS.

Men of Machines

James B. Black

1950 he was named assistant chief engineer of the General Products Div. Mr. Black came to Twin Disc in 1941 as a design engineer in the Hydraulic Div. He was promoted to assistant chief engineer in 1950.

Other promotions announced at the same time are those of **George R. Aschauer** to assistant chief engineer at the General Products Div. and **Evert L. Venstrom** to assistant chief engineer, mechanical design; **Marvin W. Dundore** to assistant chief engineer, circuit design; and **Conrad R. Hilpert** to assistant chief engineer, research at the Hydraulic Div.

Globe-Union Inc., Milwaukee, has announced the appointment of **Ronald M. Fiandt** to the newly created position of director of automotive products design and development.

A member of the engineering staff of Libbey-Owens-Ford Glass Co. since 1950, **Lloyd W. Smith** has been promoted to assistant plant engineer of the Ottawa, Ill. plant. Mr. Smith has done aircraft engine development work at Packard Motor Car Co. and was assistant chief engineer of Air-Way Electric Corp.

Roger Somerville has been appointed chief engineer of Telectro Industries Corp., Long Island City, N. Y. Mr. Somerville's previous affiliations were chief engineer of

Circle 518 on page 19

the Government and Industrial Div. of C. L. S.-Columbia, senior project engineer of Fairchild Recording Co., senior design engineer for Reeves Instrument Co. and senior project engineer of Emerson Radio and Phonograph Corp.

The Maytag Co., Newton, Iowa, has named **Charles W. Burkland** project engineer in the research and development division. Associated with the company since 1945, Mr. Burkland has been an associate research engineer.

C. C. Franck has been appointed consulting engineer at the Westinghouse Electric Corp. steam division, Pittsburgh. Mr. Franck joined the company in 1928 and has served successively as supervisor of the thermodynamics section, section manager of central station turbine engineering, subdivision manager of land turbine engineering in 1945 and subdivision manager of large turbine engineering in 1952.

Formerly vice president in charge of engineering and manufacturing, **William F. Wilson** has been named executive vice president of Gear Grinding Machine Co., Detroit. At the same time **Fred F. Miller** was made vice president of Detroit Bevel Gear Co., a Gear Grinding subsidiary. Mr. Miller was vice president of operations and director of engineering at Detroit Bevel.

Brian Sparks has been made general manager of the Aircraft Div. of Clary Corp., San Gabriel, Calif. He will continue in his present post as chief engineer. Mr. Sparks joined Clary when it acquired the Avron Corp., of which he was a founder and vice president.

Emanuel R. Piore has joined International Business Machines Corp. as director of research. Dr. Piore was formerly chief scientist of the Office of Naval Research. At IBM he will head a research effort being carried on in laboratories located in New York, California and Zurich, Switzerland.

EAGLE

time delay relay

for transmitters and other industrial or aircraft applications

Compactness . . . plus **"Mil-Spec"** precision

A complete timer, weighs only 9 ounces. Yet it passes rigid military tests for accuracy, vibration, shock, salt spray, humidity. Developed for radio and radar transmitters, now available for any application that requires this precision, space-saving timer.

As one example, this new timer (HYS series) gets electronic equipment back into service just as quickly as warm tubes reheat to safe operating temperatures. Starts operation *minutes sooner* when tubes have not completely cooled from a previous operation. It's safe. Cuts lost operating time. Standard 28V D. C. Other D. C. ranges on request. Units may be operated from 115V A. C. rectified source. Free bulletin.

------MAIL COUPON TODAY-------

Eagle Signal Corporation, Dept. MD-1156
Industrial Timers Division
Moline, Illinois

Please send Bulletin 820 with operation data and specifications on the new HYS series time delay relay.

NAME AND TITLE

COMPANY

ADDRESS

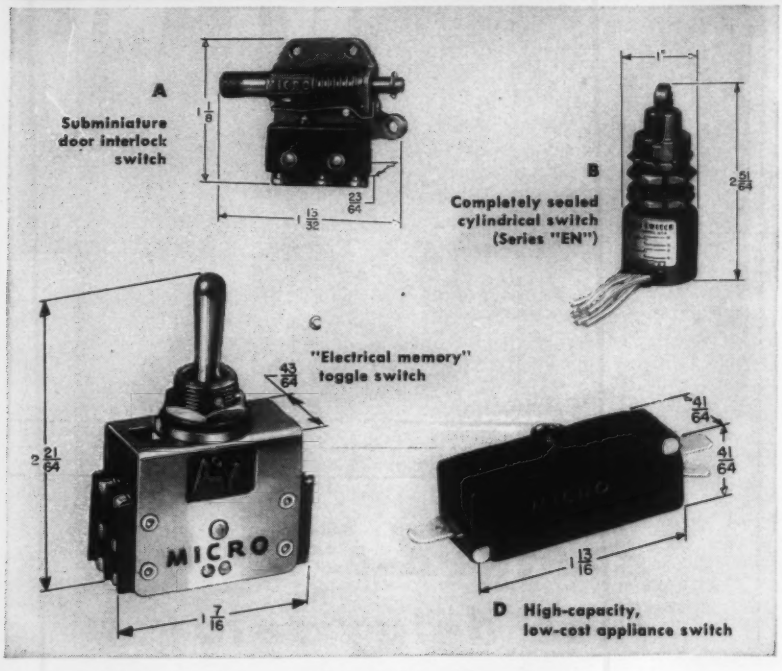
CITY ZONE STATE

Circle 519 on page 19

MICRO precision switches

...THEIR USE IS A PRINCIPLE OF GOOD DESIGN

HONEYWELL



A continuous flow of Precision Switch Developments anticipates Your design needs

MICRO precision switches are developed and built to meet specific requirements. Some designs call for the utmost precision, plus reliability. Other designs put long life and extreme reliability at the top of the list. Some must have all of these and more. Whatever YOUR requirement may be, MICRO SWITCH has a switch readily available or can work with you in its development.

Here are a few recent MICRO SWITCH *developments to meet specific needs:*

A The subminiature door interlock switch is for use where an extremely small assembly is desired to provide automatic cut-off of the power circuit when a cabinet door is opened. This switch assembly has been found extremely valuable on radio, radar, x-ray and other hazardous equipment where it is desirable to provide automatic protection to operating personnel. (*Ask for Data Sheet P108*).

B The MICRO SWITCH "EN" Series switches are capable of reliable, long-life performance under extreme environmental and mechanical conditions. They are completely sealed, cylindrical in shape and can be mounted wherever a through hole can be provided. Variations of the "EN" are capable of actuation by almost any means (see right hand column). (*Send for Data Sheet 105*).

C This is the first of a new series of "electrical memory" toggle switches being introduced by MICRO SWITCH. They offer a completely new concept in switching remotely controlled circuits. They promise to simplify basic circuit designs of radar units, computers, aircraft control panels and similar devices. The switch indicates through a pilot light or buzzer which circuit was last actuated. (*Send for Data Sheet 109*).

D MICRO SWITCH now offers a new series of low cost plastic encased switches especially designed for use on domestic appliances. In addition to their small size and high electrical capacity, these switches are ruggedly constructed for hard service. They are readily adaptable for use with auxiliary actuators. (*Send for Data Sheet 106*).

See the unusual design flexibility of the new MICRO Series "EN" switches

Spring return adjustable actuator for cam or slide actuation
Roller plunger actuator for actuation by cams and slides

MICRO SWITCH *Engineering service is available at nearby branch offices. A call can save you time and money.*

MICRO SWITCH

A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

In Canada, Leaside, Toronto 17, Ontario • FREEPORT, ILLINOIS

TORRINGTON PRESENTS:

An important new line of complete blower units for central air conditioning, heating and ventilating, in a wide range of sizes, full and three-quarter widths, and incorporating the following exclusive Torrington features:

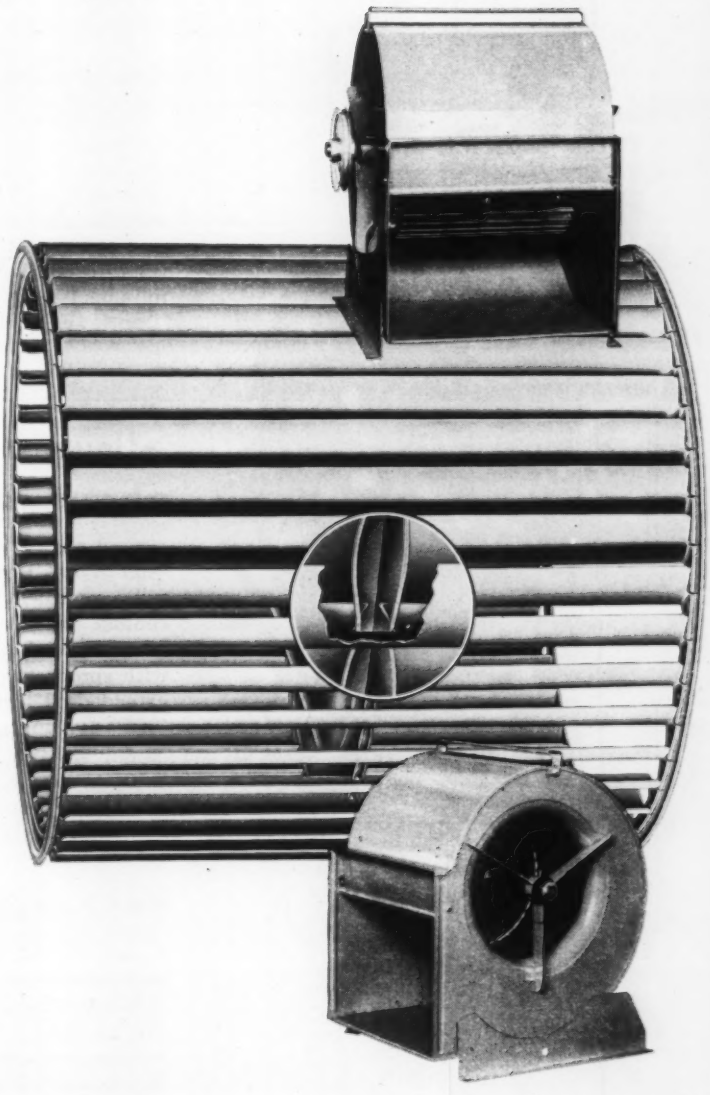
1. An exceptional new Center-Lock airotor introducing an entirely new principle of blower wheel construction in which (see insert) the center disc is dovetailed under pressure into the encircling blades. As a result of this design feature, the interlocking joint *tightens* under centrifugal force, eliminating blade rattle and angle warp at high speeds.

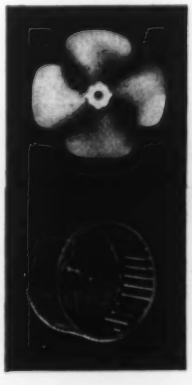
2. A Multi-Position blower housing, easily adaptable to left or right, up or down flow requirements, of the finest welded steel construction and special finish.

3. Availability in either belt-driven or direct drive assemblies.

4. Unit flexibility, providing feet, motor mounting assembly to meet your individual mounting requirements.

This new product line is a major development backed by all the standards of engineering quality consistent with Torrington leadership in the air impeller industry. Your inquiries are invited.





THE
TORRINGTON
MANUFACTURING COMPANY
TORRINGTON, CONNECTICUT
VAN NUYS, CALIFORNIA · OAKVILLE, ONTARIO

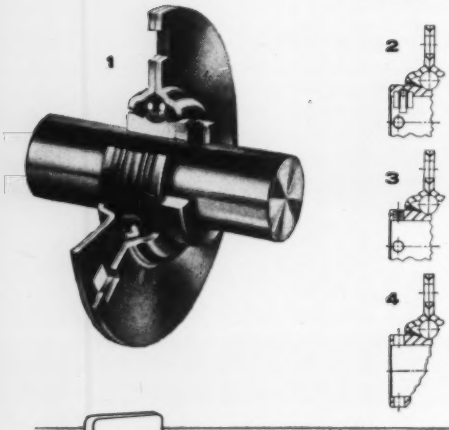
Circle 521 on page 19

XUM

Aetna

SEALED, PRE-LUBRICATED BALL BEARING package UNITS

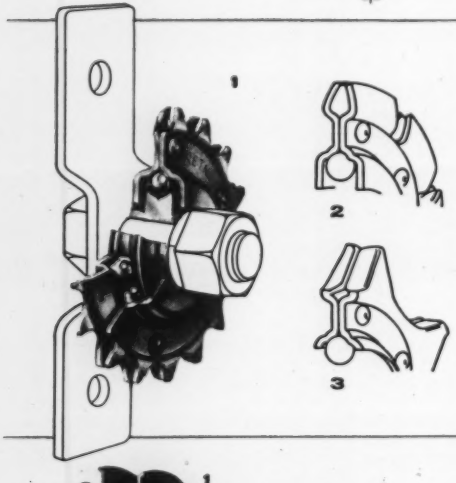
Easy To Apply . . . Require No Maintenance . . . Inexpensive



ADAPTER UNIT

Designed for light-duty moderate-speed applications, this multi-purpose economy-priced unit mounts easily, quickly, wherever shafts can be supported—on sheet metal or any semi-rigid structural members. Sealed, pre-lubricated bearing is self-aligning; takes radial, thrust or combined loads. Available in 4 shaft-locking types, (1) with eccentric locking collar,* (2) with ball lock,‡ (3) with two set screws,‡ (4) drilled for roll-pins.‡

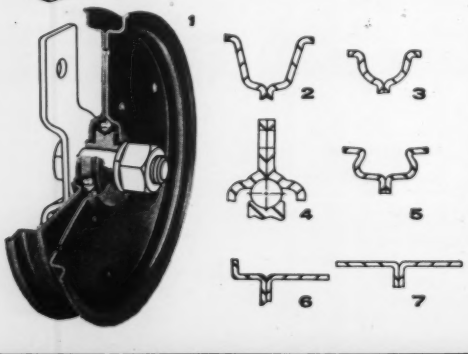
*Standard ‡On special order



SPROCKET IDLER UNIT

A sprocket idler and pre-lubricated, sealed, ball bearing —*all-in-one*. Bearing has triple-capacity lubricant chamber, full complement of balls for greater load capacity, 4-point ball contact for greater rigidity, case-hardened inner and outer races. Bore sized for ⅜" or ½"* mounting bolts—available with sprockets (as illustrated) to fit (1) standard pitch, (2) extended pitch roller chain or (3) detachable link chain.

*On special order



BELT IDLER UNIT

Designed and built-to-be-installed-and-forgotten this permanently lubricated, sealed-for-life idler unit requires no re-lubrication, no maintenance of any kind. It combines bearing, seals, and pulley in a single, compact, easy-to-install *package* assembly. Bore sized for ⅝" or ½"* mounting bolts. Sheaves (available in 7 types illustrated) and bearing outer race are of heavy-gauge, case-hardened steel.

*On special order

GET THE FACTS . . .

See how these low-cost units can be adapted to either your current or projected equipment designs with minimum, or no, engineering alterations. Write us or call in our local expert, your nearby Aetna distributor.

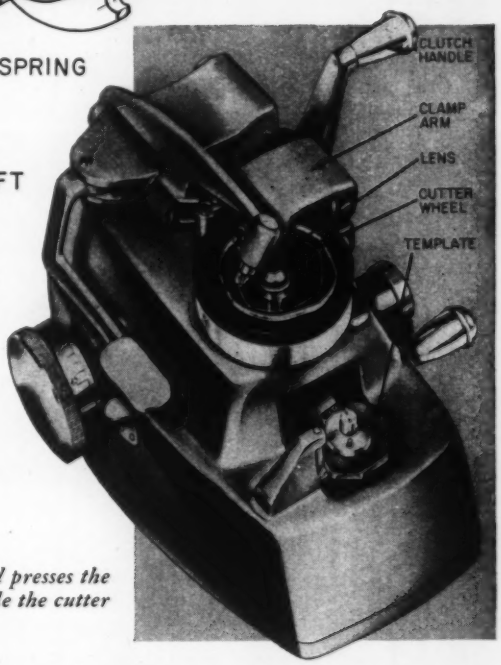
Aetna

40 YEARS

AETNA BALL AND ROLLER BEARING COMPANY
Division of Parkersburg-Aetna Corporation
4611 Eddystone Ave., Philadelphia 37, Penna.

FIRM, STEADY PRESSURE
assures accuracy in lens cutting

Exploded view of Marquette PrecisionSpring Bi-directional No-back Clutch in American Optical M-542 Lens Cutter



A turn of the clutch handle lowers the clamp arm and presses the lens firmly against the lens pad. The lens revolves while the cutter wheel, guided by template, cuts it to exact shape.

This Marquette PrecisionSpring Clutch provides constant and uniform pressure, with minimum back-lash. It assures dependable, trouble-free performance—and saves the operator's time.

The input shaft can be rotated in either direction, and drives the output shaft in the same direction at the same speed. But when torque is applied to the output shaft (either clockwise or counter-clockwise) the clutch will lock securely and the output shaft will not rotate.

Marquette Spring Clutches have given dependable service for many years in a wide range of applications—from Aircraft to X-ray. They require very little space. They maintain their efficiency almost indefinitely. And they cost much less than other types of clutches.

Send the coupon for complete descriptions and drawings of:

OVER-RUNNING or FREE-WHEELING CLUTCHES
BI-DIRECTIONAL NO-BACK BRAKES • REVERSING CLUTCHES • SINGLE REVOLUTION CLUTCHES.

MARQUETTE METAL PRODUCTS DIVISION
CURTISS-WRIGHT
CORPORATION • CLEVELAND 10, OHIO

Other Marquette Products:
ANTI-FRICTION BEARING TEXTILE SPINDLES
HYDRAULIC GOVERNORS • AIRCRAFT WINDSHIELD WIPERS
ROTARY OIL PUMPS • PRECISION PARTS AND ASSEMBLIES.

MARQUETTE METAL PRODUCTS DIVISION
1143 Galewood Drive, Cleveland 10, Ohio

Please send information on the functions, applications, and operation of the basic types of PrecisionSpring Clutches.

COMPANY

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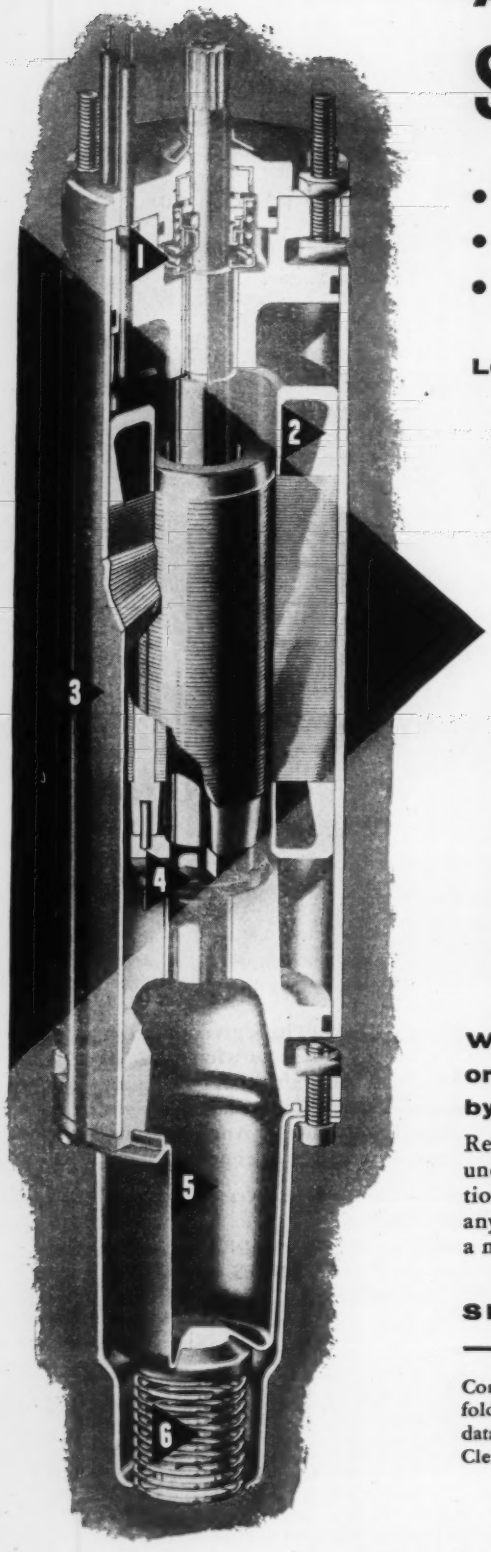
ADDRESS _____

Circle 523 on page 19

XUM



Announcing a *CUSTOMIZED*

SUBMERSIBLE MOTOR

- **that fits in a small-diameter casing**
- **that gives you high output**
- **that runs in water, oil or other fluids**

Look at typical features of a J&H Underwater Motor

1 *Rotary Seal*—Ceramic and graphitar faces, carefully lapped to insure against entry of water and contaminants.

2 *Encapsulated Windings*—A special J&H epoxy compound is used for "potting." Epoxy has exceptional heat conductivity and does not buckle or swell under many abnormal conditions. "Potting" prevents winding failure, even if water enters motor. In fact, motor will operate as water-filled unit.

3 *Corrosion-resistant Epoxy Paint Finish.*

4 *Segmented Tilting-shoe Self-aligning Thrust Assembly*—Ample reserve thrust carrying capacity is provided. Faces accurately lapped for long wear.

5 *Oil-filled Motor*—A large reservoir of oil provides additional dielectric strength, insures longer seal and bearing life, protection against corrosion.

6 *Controlled Pressure System*—Diaphragm and spring assembly insures an internal pressure sufficient to prevent infiltration by external contaminants, which could occur with normal seal wear.

● *L/D Ratio To Suit*—Length/diameter ratio can be varied to fit casing, tank, pipeline or other designated location.

Whether you're pumping water, crude oil, gasoline or other fluids, your motor need can be met quickly by Jack & Heintz!

Retaining the size flexibility and long service life features of the underwater motors, J&H designers have already developed modifications for operation in crude oil, gasoline and other fluids. Customizing any of the proved basic designs to meet your specific needs is only a matter of defining your service and dimensional requirements.

SEND FOR DATA TODAY

Confer with J&H motor specialists or write for folder which gives rating and performance data: Jack & Heintz, Inc., 17626 Broadway, Cleveland 1, Ohio.

©1956 by Jack & Heintz, Inc.

JACK & HEINTZ ***CUSTOMIZED*** ELECTRIC MOTORS

GOLD-N-RING ... a new name and a new conception of CONTROL SWITCH design

HEAVY-DUTY

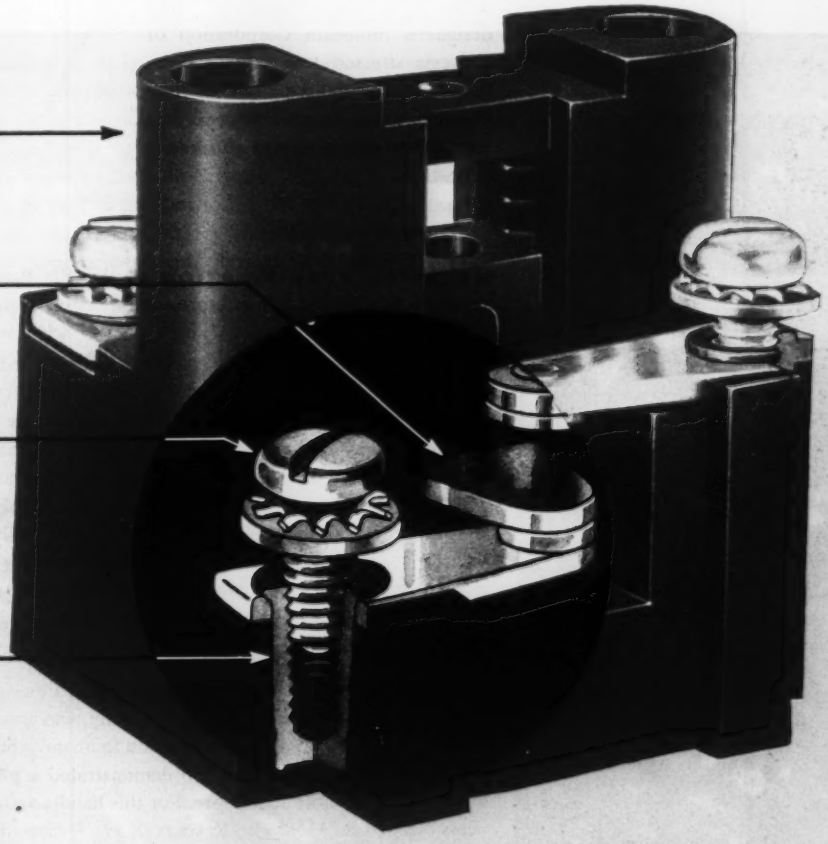
OIL-TIGHT—WATER-TIGHT—DUST-TIGHT

made by machine tool builders to machine tool specifications

A new name—GOLD-N-RING Sealtight Control Switch! A new conception—a control switch *designed and built BY a manufacturer of machine tools—FOR machine tool builders!*

A product of the same machine tool background responsible for Namco Solenoids and Snap-Lock Limit Switches, it gives designers a *package of greater electrical efficiency*—available from a single source, with a single source responsibility.

Shown here are only a few of many reasons why the GOLD-N-RING Control Switch makes it possible to match machine tool mechanical ruggedness with equally durable electrical efficiency.



1 **MAIN BLOCK is unit-molded to assure alignment and simplify assembly.**

2 **HEAVY-DUTY SILVER-ALLOY CONTACT POINTS for maximum electrical capacity and long life.**

3 **HEAVY-DUTY TERMINAL SCREWS, with 3/8" thread contact, prevent stripping during installation; permanently secure wires for continuous trouble-free service.**

4 **BRASS INSERTS MOLDED IN THE BLOCK permanently hold stationary contacts. They also provide more thread support for the No. 8-32 terminal screws that are equipped with captive flat and lock type washers.**

For complete details, send for Bulletin ECS-56. Better yet, ask for a representative to bring a switch for your examination.

ELECTRICAL MANUFACTURING DIVISION

National Acme

THE NATIONAL ACME COMPANY • 188 EAST 131ST STREET • CLEVELAND 8, OHIO

Circle 525 on page 19

Craftsmanship of the 20th Century

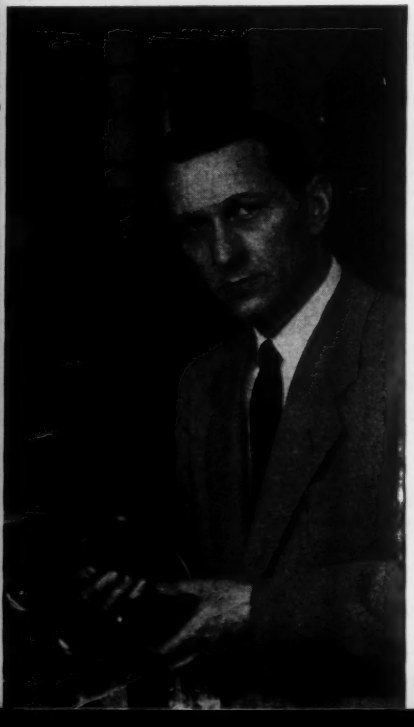
MONSANTO

The speed with which new products pass through the designing stage to final marketing is one of today's industrial phenomena. One factor which has contributed heavily to this is the availability of a wide range of plastic materials with highly usable combinations of properties. And, collaterally, there are the custom molders whose working knowledge and craftsmanship in plastics translate the manufacturer's designs and plans into highly serviceable, highly attractive finished articles. Read how one of America's leading appliance manufacturers collaborated with the custom molder to produce the part that "makes" his new appliance.

New handle of Resinox phenolic plastic houses "the brain" of the new Sunbeam Fry-Pan

DESIGN OBJECTIVES To design the handle for the Sunbeam Fry-Pan, an aluminum frying pan, electrically wired to "do its own cooking." To its designers, Sunbeam Corporation of Chicago stressed two things: functional beauty and long service life. Cost, of course, as on all high-volume competitive products, was also a consideration.

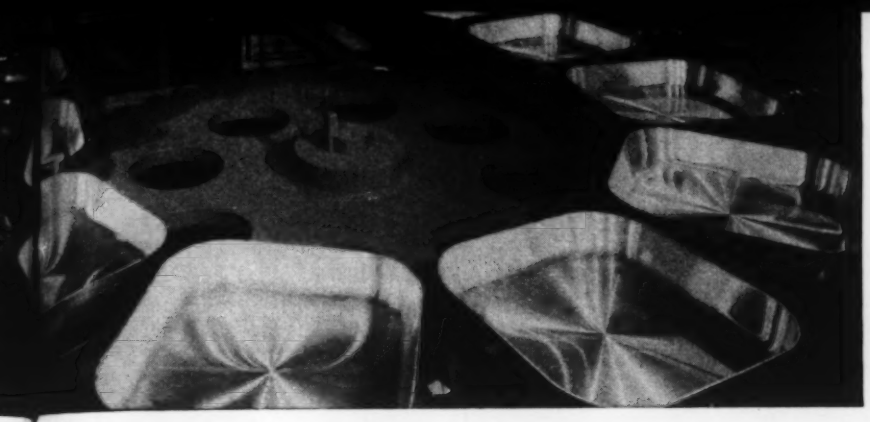
MATERIAL SPECIFICATION In the Fry-Pan, the handle is the "brain"—housing the temperature setting controls, signal light, and automatic regulators that govern the 1150 and 1450 watt tubular element sealed in the base of the pan. Specifications dictated that this handle be inserted into the apertures of the thermostat, then sealed in 3 seconds by a Hannifin hydraulic press. Over 30 exhaustive tests were made to screen different materials in the conditions to which the handle would be subjected in use. Surface finish and hardness, resistance to detergents and boiling water, weight, dielectric strength, and durability were all major factors in determining the material. Monsanto Resinox phenolic plastic was selected. A handle molded of this phenolic had a high natural surface gloss, heat-resistance, and inherent color. It could be repeatedly immersed in boiling water with no ill effects . . . was tough and long lasting.



Chief Mold Designer for Prolon Plastics Co., Mr. Clyde Morrell.

PRODUCTION Prolon Plastics Company, Florence, Massachusetts, a division of Pro-phy-lac-tic Brush Company, was awarded the job of producing the Fry-Pan handles. In addition to an enviable reputation for high quality molding, Prolon had also demonstrated a productive capacity to meet Sunbeam's production rate. For this handle assignment, Prolon engineers decided on Monsanto Resinox 5797. A free-flowing phenolic molding compound, Resinox 5797 has rapid cure and rigid set, two reasons for its wide use for wiring device parts. It produces parts with a very smooth,

Circle 526 on page 19



hard surface. Equally important, Resinox 5797 meets the critical heat requirements on the Fry-Pan where heat is constantly re-applied to this molded handle. Using Resinox 5797, Prolon molded a handle with a life expectancy far exceeding the required 2000 hours. In fact, if the housewife uses her Sunbeam Fry-Pan with its Resinox handle for 7 hours a week, 52 weeks of the year, she can expect over 5½ years of service under such severe usage.

THE FINISHED PRODUCT The popularity of the Sunbeam automatic Fry-Pan is a tribute to the usefulness of this work-saving kitchen appliance. Practical usefulness has been achieved by following the precepts of functional design and simplicity of form. The jet black lustrous handle of Resinox phenolic plastic adds a high note of functional beauty.

Here is one of the hundreds of design and production problems solved by utilizing the facilities of the plastics custom molding industry. If you are considering a design change or new product, investigate plastics, and the design, engineering, and molding facilities available to you through plastics molders, the Craftsmen of the 20th Century. As a major supplier of plastic resins, Monsanto is in a position to introduce you to custom molders who will put their skills to work for you. Write to Monsanto Chemical Co., Industrial Applications Dept., Springfield 2, Mass.

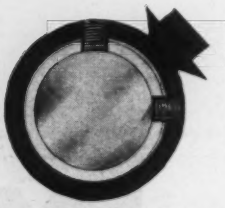
Investigate Monsanto's complete line of phenolic plastic compounds developed for particular applications and sold under the trade name...

RESINOX®

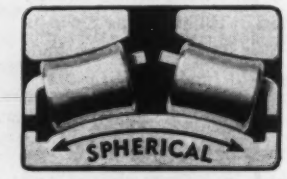
MONSANTO

MORE FACTS on why more and more leading manufacturers choose Link-Belt bearings

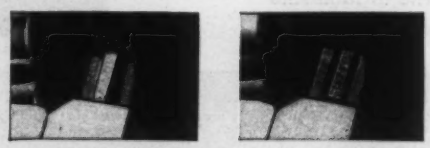
EASY, LOW-COST INSTALLATION—Series 400 bearing blocks are quickly mounted on commercial shafting from ¾ to 4-in. diameters.



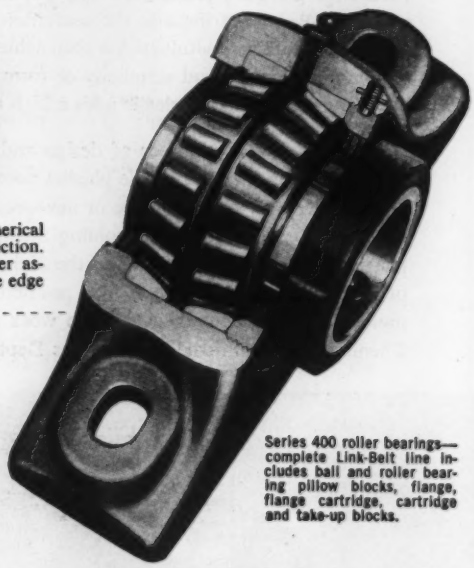
HEAVY COLLAR SECURELY LOCKS INNER RING TO SHAFT. Use of setscrews in collar avoids distortion of inner ring. Tension of collar against heavy setscrews assures tightness.



FREE ROLLING—SELF-ALIGNING. Spherical inner ring is free to align in any direction. Load is distributed over entire roller assuring full load capacity. Destructive edge loading cannot occur.



CONTACT-TYPE SEAL, left, of felt laminated with synthetic rubber for extremely dirty conditions. **LABYRINTH SEAL,** right, for normal conditions. Bearings are pre-lubricated and sealed at factory.



Series 400 roller bearings—complete Link-Belt line includes ball and roller bearing pillow blocks, flange, flange cartridge, cartridge and take-up blocks.

Fast, easy mounting

—a key feature of these self-aligning, high-capacity roller bearings

● Hundreds of equipment manufacturers who use roller bearings choose the popular, high-capacity Link-Belt Series 400. Compactness promotes neatness of machinery design . . . easy mounting reduces installation costs. And field service has developed an unmatched performance reputation because of many valuable features.

Series 400 pillow blocks are equipped with self-aligning, double-row roller bearings. Even under shaft deflection and misalignment, bearing maintains full load capacity during its long life.

This quality bearing is part of industry's most complete line of ball and roller bearing blocks—made at a Link-Belt plant devoted exclusively to these precision products. For Book 2550 on the full line—ask one of the 40 Link-Belt offices nearest you.

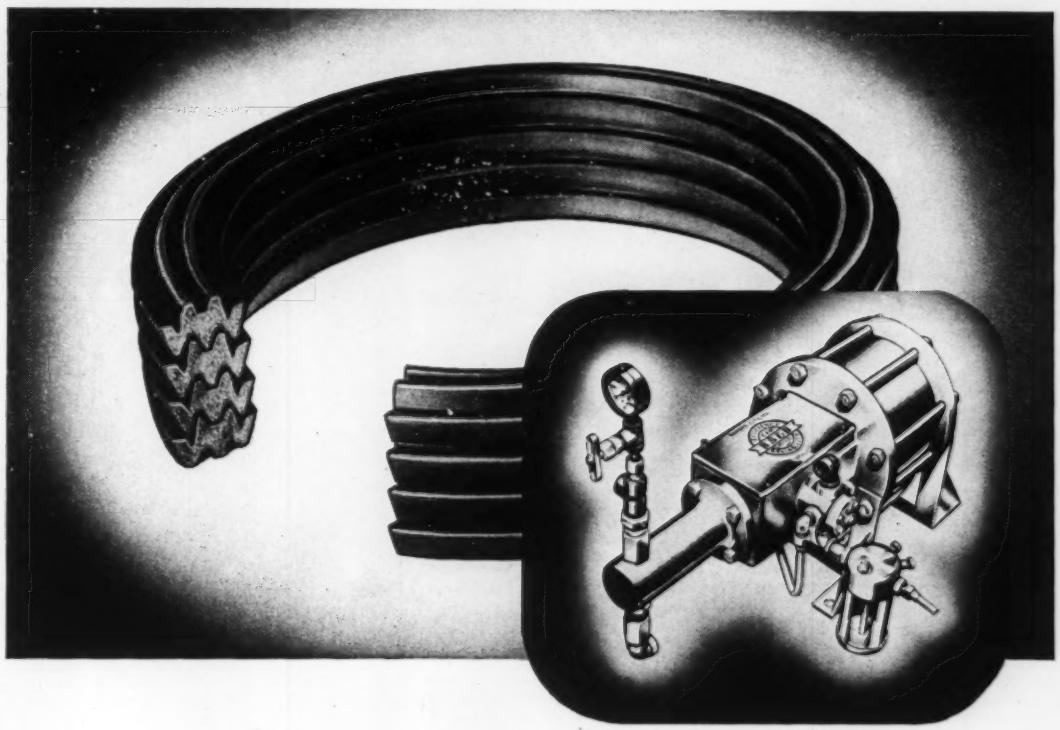
LINK-BELT

Ball and Roller Bearings

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office: New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13.980-A

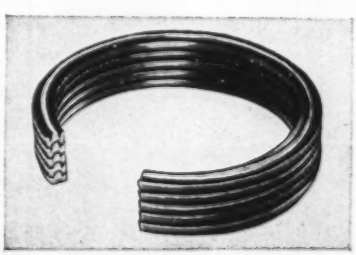
Circle 527 on page 19

J-M Uneepac® does it again!



"Very satisfactory sealing service against wide variety of fluids and pressures up to 5,500 psi"

says Black, Sivalls and Bryson, Inc. makers of BS&B Glycol Pump



Uneepac comes in two types. Shown here is design for flange widths up to ½" which is used in BS&B Glycol Pump. Large illustration above shows design for flange widths over ½".

Chalk up another success story for Uneepac—Johns-Manville's automatic ring packing. In the BS&B Glycol Pump, fluids handled include triethylene glycol, diethylene glycol, gasoline, and various types of oils, alcohols and petroleum treating chemicals. Working pressures range from 125 psi to 5,500 psi with average operating pressures at 3,000 psi. Yet despite these rugged service conditions, Uneepac has delivered—in Black, Sivalls and Bryson's own words—"very satisfactory service."

Many other packing users have acclaimed J-M Uneepac for its long, trouble-free service. Each ring is a complete packing unit. Fewer rings are needed than ordinarily required and stuffing box size can be reduced to the minimum. Each ring centers itself automatically on the preceding ring to simplify installation. This exclusive design also permits fluid pressure to act upon each lip individually and protects lips from excessive gland pressure.

J-M Uneepac comes in a wide range of styles and sizes for many rod and plunger applications. For further information write Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

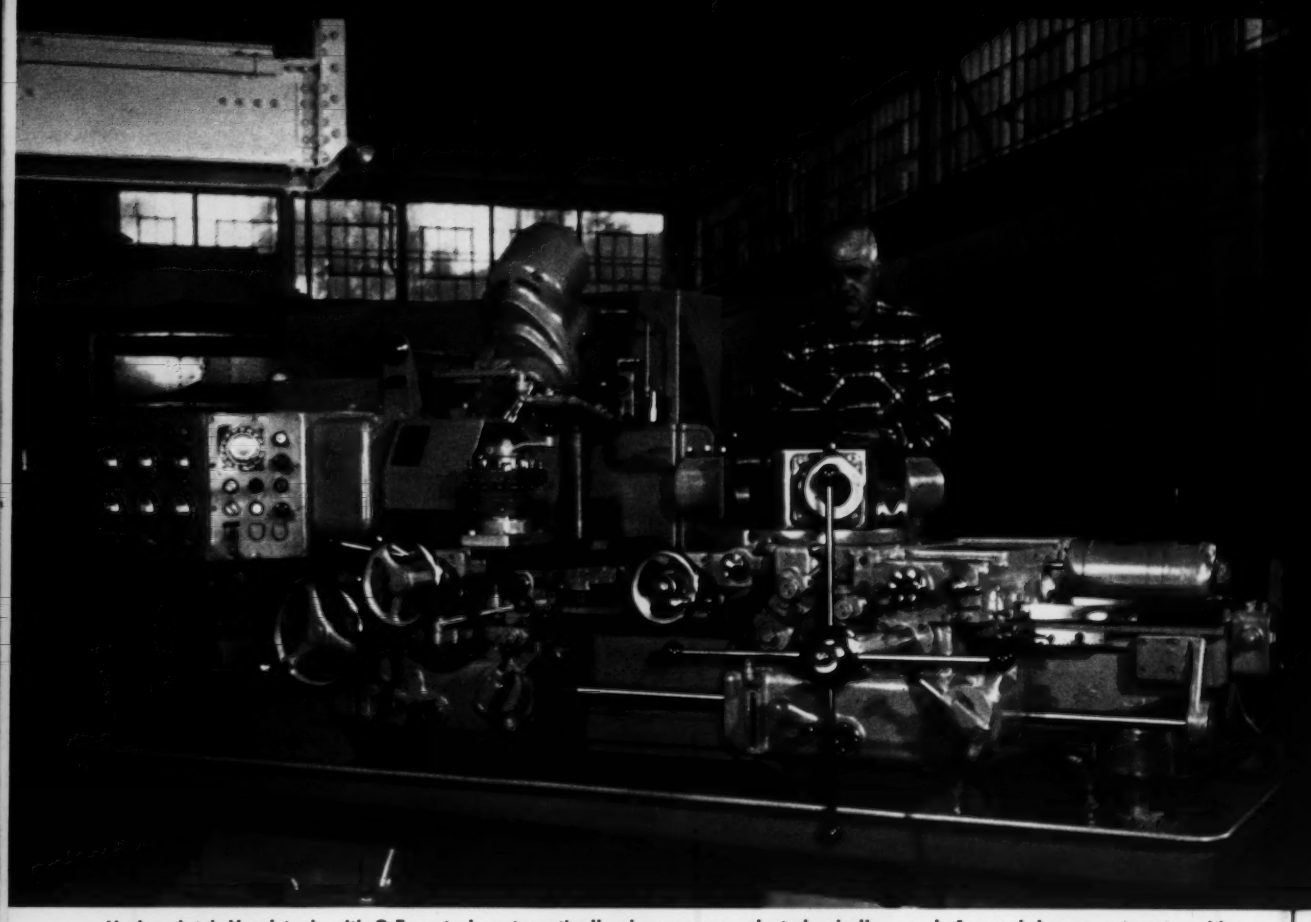
Johns-Manville PACKINGS, GASKETS and TEXTILES

Circle 528 on page 19

Circle 529 on page 19→

XUM

G-E general purpose control



Hydra-clutch Headstock with G-E controls automatically changes pre-selected spindle speeds for each hexagon turret position.

G-E PANEL PROVIDES AUTOMATIC SPEED SELECTION FOR EACH OF 6 TURRET FACES

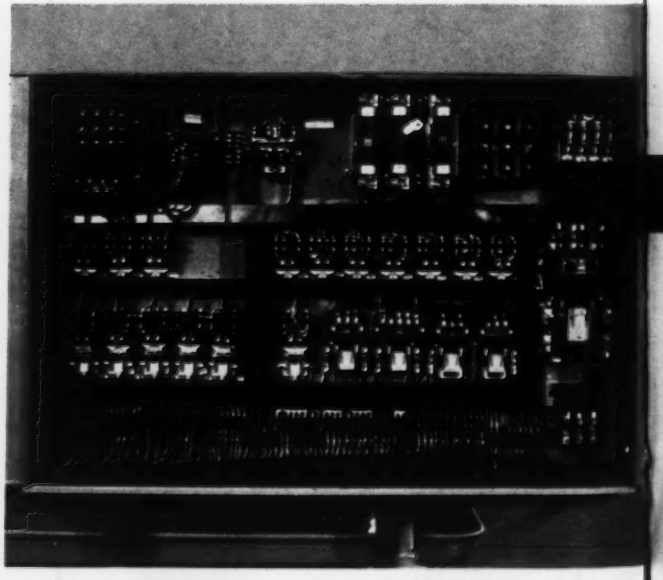
The new Hydra-clutch Headstock manufactured by the Jones & Lamson Machine Company is controlled by a General Electric factory-built Pan-A-trol packaged control panel. This machine is designed to reduce machine handling time and operator fatigue.

Equipped with a power indexed hexagon turret, the Headstock features pre-selected spindle speeds which are automatically changed for each of the six turret faces. Speed selection and changes, and power indexing are controlled by G-E oil-tight push buttons and selector switches, along with indicating lights, in the operator's station.

The factory-built panel is constructed to JIC standards, and contains standard high-quality G-E starters, machine tool relays, pneumatic time-delay relay, and other devices. The machine tool relays control the power feed and indexing of the turret head.

Latched-in forms of the machine tool relay control solenoid valves. Spindle speed changes are accomplished by these valves engaging or disengaging hydraulically operated multiple-disc clutches.

This Pan-A-trol packaged control panel was shipped from our factory completely wired. Only connections from the machine to the panel terminal board had to be made.



PAN-A-TROL PANEL was factory-built to JIC standards. Panel provides: motor starting; motor reversing; motor overload protection; over-current protection; and a disconnecting means.

XU

l on machines for industry

GENERAL ELECTRIC'S NEW

Machine Tool and Time-Delay Relays Control New 32-speed Headstock

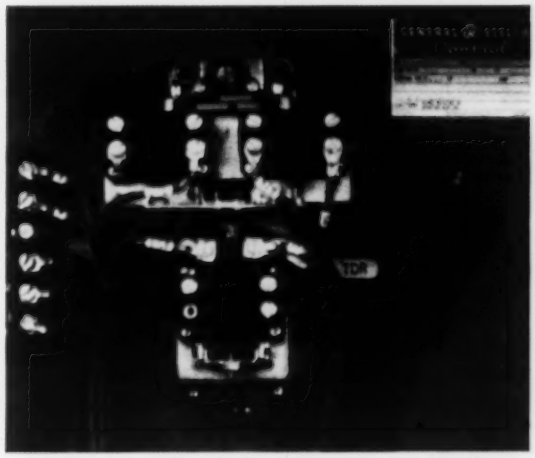
General Electric's new machine tool relays and pneumatic time-delay relay, installed in a G-E factory-built Pan-A-trol* packaged control panel, provide precise control for this 32-speed Hydra-clutch Headstock, manufactured by Jones & Lamson Machine Company of Springfield, Vermont.

MACHINE TOOL RELAYS offer a high degree of dependability on automatic machinery such as this Headstock. The Strongbox coil in the machine tool relay is molded in a polyester resin to seal out moisture and oil. Permanently attached contact springs assure proper tip pressure. Also, contacts change from normally open to normally closed without extra parts.

PNEUMATIC TIME-DELAY RELAY provides high repetitive accuracy with negligible effect from humidity or atmospheric pressure changes. It is adjustable from 0.2 to 180 seconds. A rigid die-cast aluminum base prevents misalignment which might affect relay accuracy.

FOR MORE INFORMATION, contact your nearest General Electric Apparatus Sales Office, or write Advertising and Sales Promotion, Section 731-4, General Electric Company, Bloomington, Illinois.

* Trade-mark of General Electric Co.



PNEUMATIC TIME-DELAY RELAY prevents operation of power wrench on Headstock before it stops spinning.

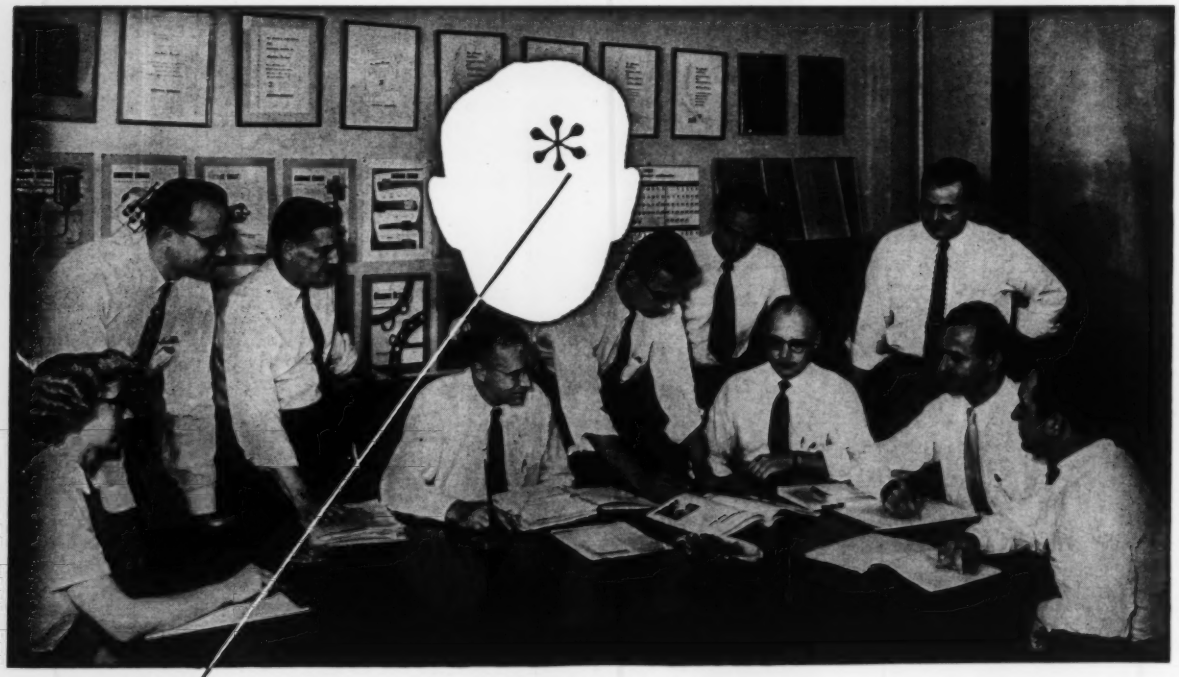
GENERAL ELECTRIC

GENERAL ELECTRIC'S MACHINE TOOL RELAY FAMILY

MACHINE TOOL RELAYS have front-connected terminals, can be wired from four directions for easier installation. Also, three keyhole slots simplify mounting the relay.

LATCHED-IN FORMS have a standard machine tool relay plus a latching mechanism, which mechanically holds the contacts closed to maintain the continuity of sequencing.

XUM



A Challenging Engineering Opportunity . . .

Technical Editor Wanted

• Here is your chance to gain a broad knowledge of the design engineering field and related activities.

• Edited for engineers, by engineers, MACHINE DESIGN has an opening on the editorial staff for a man with enthusiasm both for engineering and for writing and editing.

• He will work on a stimulating job that provides interesting contact with diversified problems in a variety of engineering areas.

• Additionally he will be encouraged to progress as a specialist in one or more of the branches of design engineering.

• He should have had some design experience, and an EE or ME degree would be desirable.

• He should be able to write fluently and well, and should show evidence of such ability.

• Duties include the procurement, selection, writing and editing of articles and feature departments.

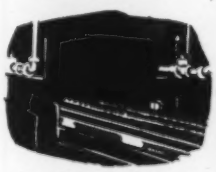
• Headquarters are in Cleveland, with opportunities for travel to attend meetings and expositions and to seek material for publication.

• If you are interested and feel qualified, send full details of your engineering and writing experience to the Editor, MACHINE DESIGN, Penton Building, Cleveland 13, Ohio.

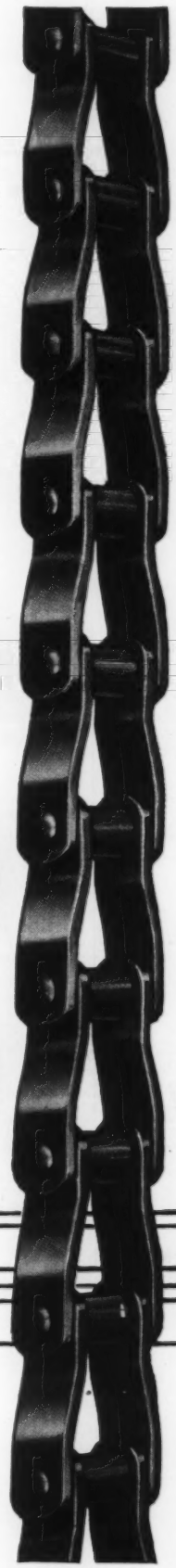
Construction Machinery

Assembly Conveyors

Drilling Equipment



Heat-Treating Furnaces

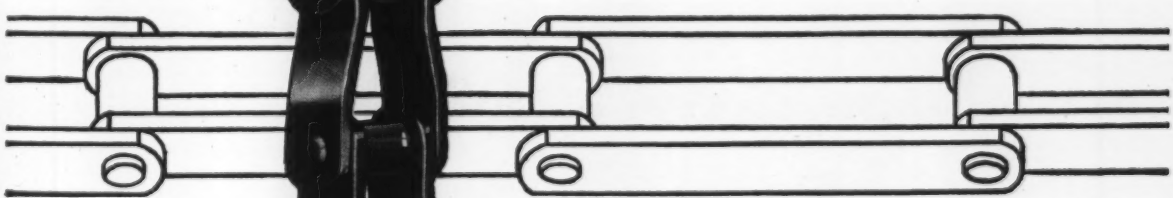


When COST is an OBJECT

Whether that cost is first or operating, it will pay dividends to investigate the saving possibilities of Rex Chabelco Steel Chain. It has the *extra* strength, *extra* stamina and *extra* quality needed for longer trouble-free operation.

For drive or conveyor service, where loads are heavy, speeds slow to moderate... where operating conditions involve temperature extremes, dust, dirt or heavy shock loads—*these steel chains will save you important money.* And, they run on cast sprockets... another important cost-cutting advantage.

Why not have your Chain Belt Field Sales Engineer check your chain requirements with you. He may be able to save you important money—he has for other Design Engineers. Meanwhile, send for Bulletin 56-57. Chain Belt Company, 4643 W. Greenfield Ave., Milwaukee 1, Wisconsin.

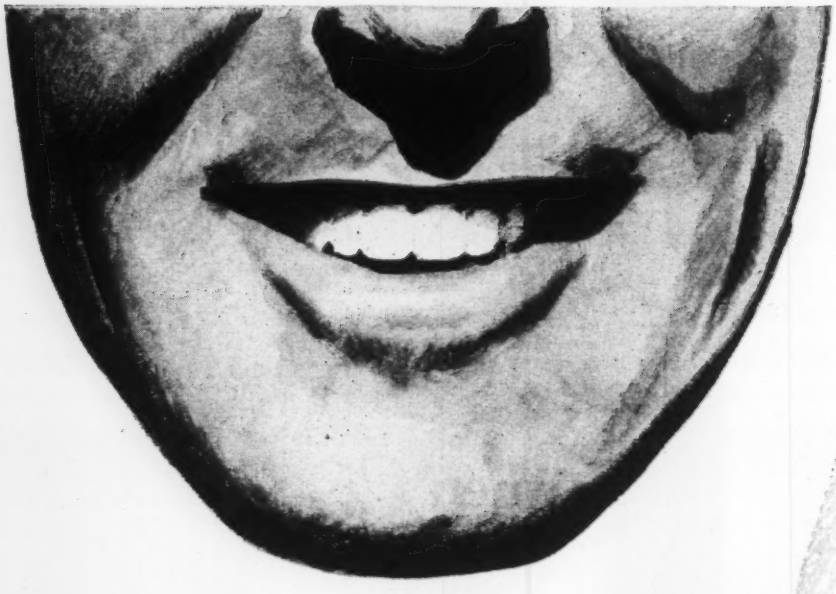


CHAIN BELT COMPANY

District Sales Offices in all Principal Cities

Circle 531 on page 19

XUM

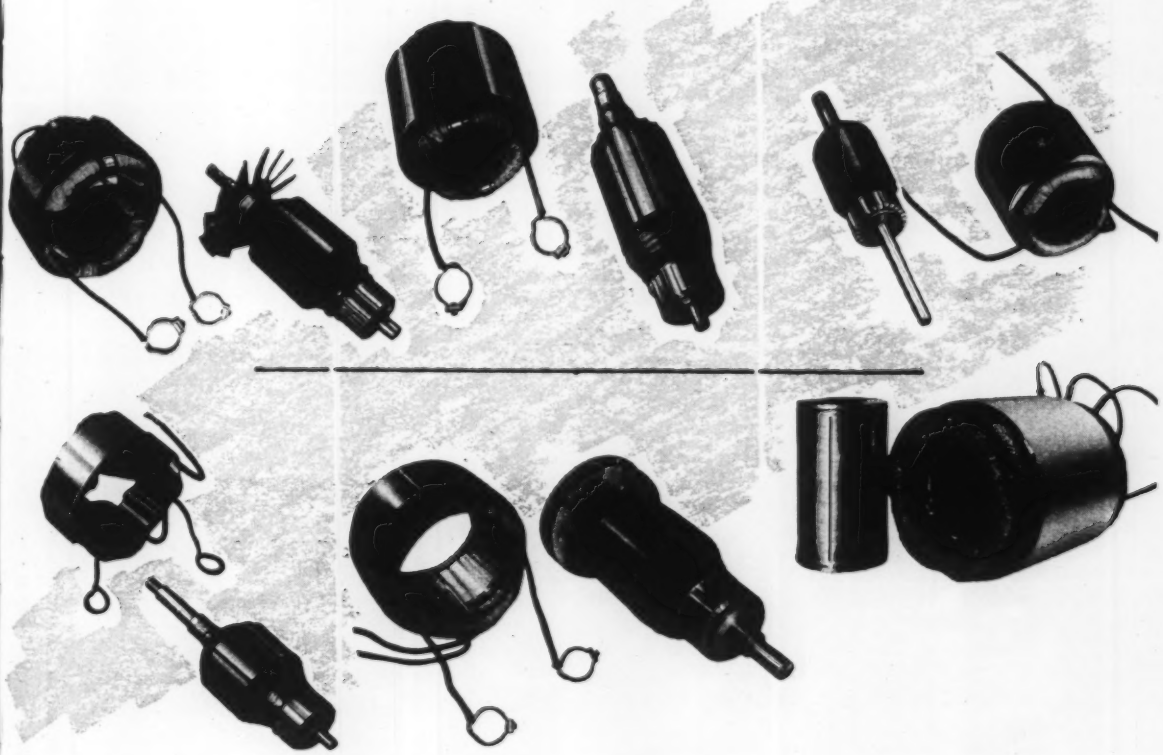


R & M MOTOR PARTS

...put Extra
Customer Satisfaction
in the heart of
your product!

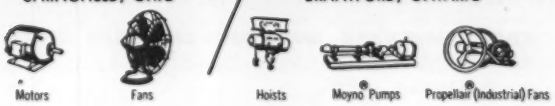
Your customers get added satisfaction where it counts because every R & M motor part is carefully designed and precision manufactured to provide dependable power at the flick of a switch . . . even after years of rugged use!

R & M's broad line and experience as major suppliers of standard motor parts to hundreds of manufacturers since 1928 assure you of sound judgment in recommending the correct motor parts for your application. You will find R & M application engineers well qualified and eager to work with you on any application requiring series, universal or polyphase high-cycle motor parts. Write today for R & M bulletin 455-MD and the name of the R & M Field Engineer in your area.



ROBBINS & MYERS, INC.

SPRINGFIELD, OHIO / BRANTFORD, ONTARIO



Motors · Fans · Hoists · Moyno® Pumps · Propellair® (Industrial) Fans

Circle 532 on page 19

XUM

Only your *imagination*

limits the ways you can use Ampco Alloys

That . . . and the requirements of the part you're designing

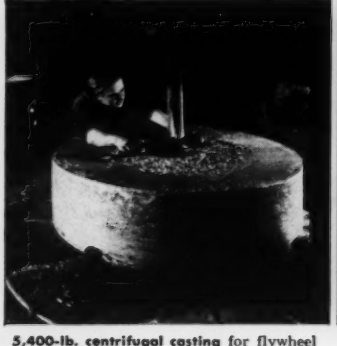
Should your part be sand-cast, centrifugally cast, shell-molded, precision-cast, forged, fabricated or extruded?

Let an Ampco field engineer help you to select the best, most economical form of production. It's all part of Ampco's one-source service to industry.

And he can help you select the best alloy, too. For among more than 100 Ampco copper-base alloys is the one you need to do the job — to resist wear, corrosion, impact, fatigue — to provide excellent bearing qualities — to retain physical characteristics at temperatures from 600°F down to −400°F.

So call in your Ampco field engineer and get his unbiased recommendations.

Write for Bulletin 33. D-53



5,400-lb. centrifugal casting for flywheel of a marine engine. Ampco makes centrifugal castings from a few pounds to five tons.

12,000-lb. sand-cast water wheel. Ampco's sand foundry makes any-size casting to 14,000 pounds — sand, shell moldings, cast-to-size, cement.

Ampco's one-source service includes production-run machining of Ampco copper-base alloys to the exacting quality standards of the aircraft industry.

AMPCO METAL, INC. Dept. MD-11, Milwaukee 46, Wisconsin • West Coast Plant: Burbank, California

AMPCO® **THE METAL WITHOUT AN EQUAL**

SAND CASTINGS

SHELL-MOLDED CASTINGS

CENTRIFUGAL CASTINGS

EXTRUSIONS

FABRICATIONS

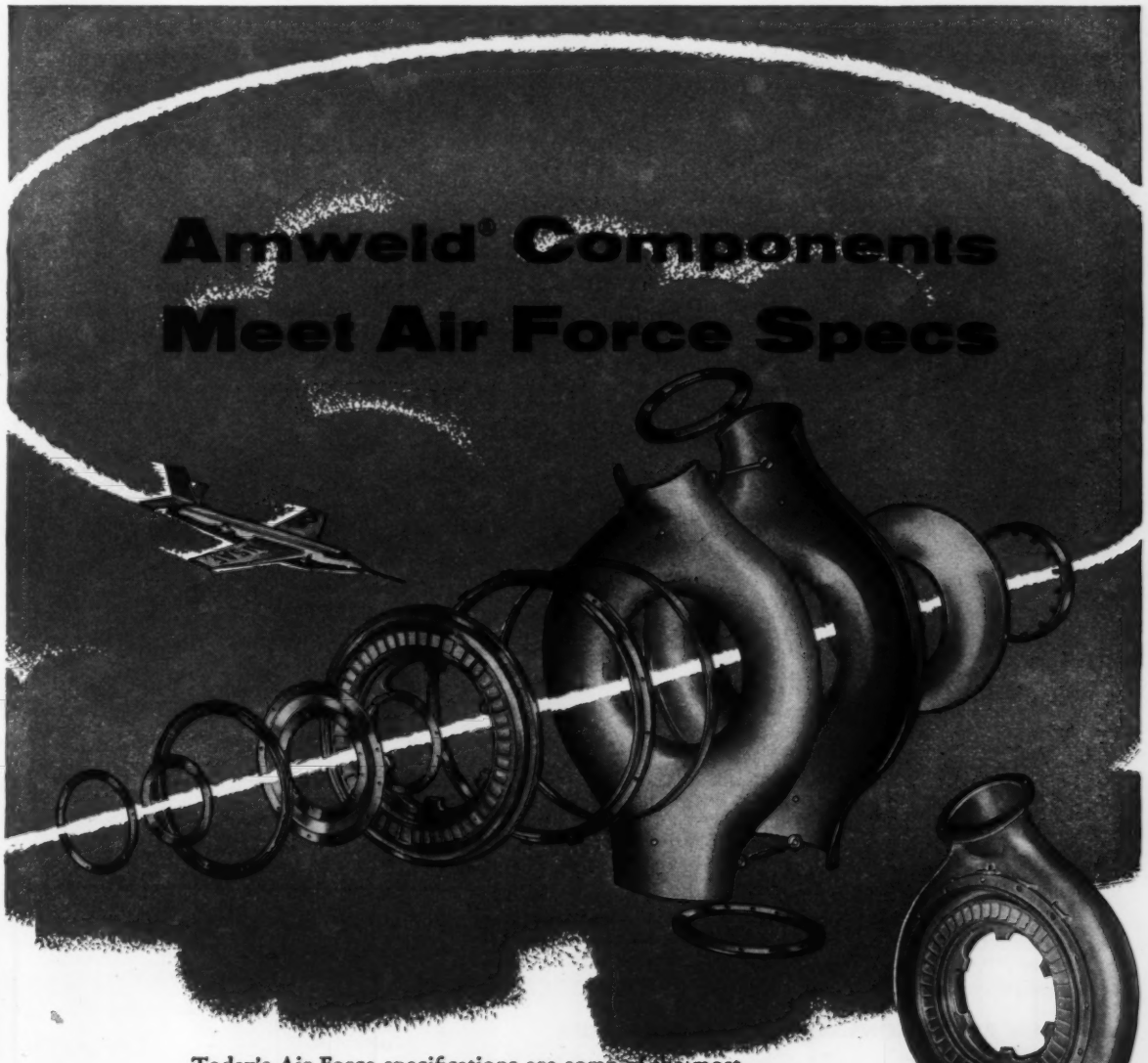
SHEET AND PLATE

CAST-TO-SIZE CASTINGS

FORGINGS

MACHINED PARTS

Amweld® Components Meet Air Force Specs



Today's Air Force specifications are some of the most rigid known to industry. For example, during the assembly of this nozzle box, which is used on a turbosupercharger, more than 30 inspections are required. This nozzle box is assembled by fabricating 68 parts of 24 different types of material, using 6 different types of welding. The finished component must have the same tensile strength and original characteristics as the parent metal.

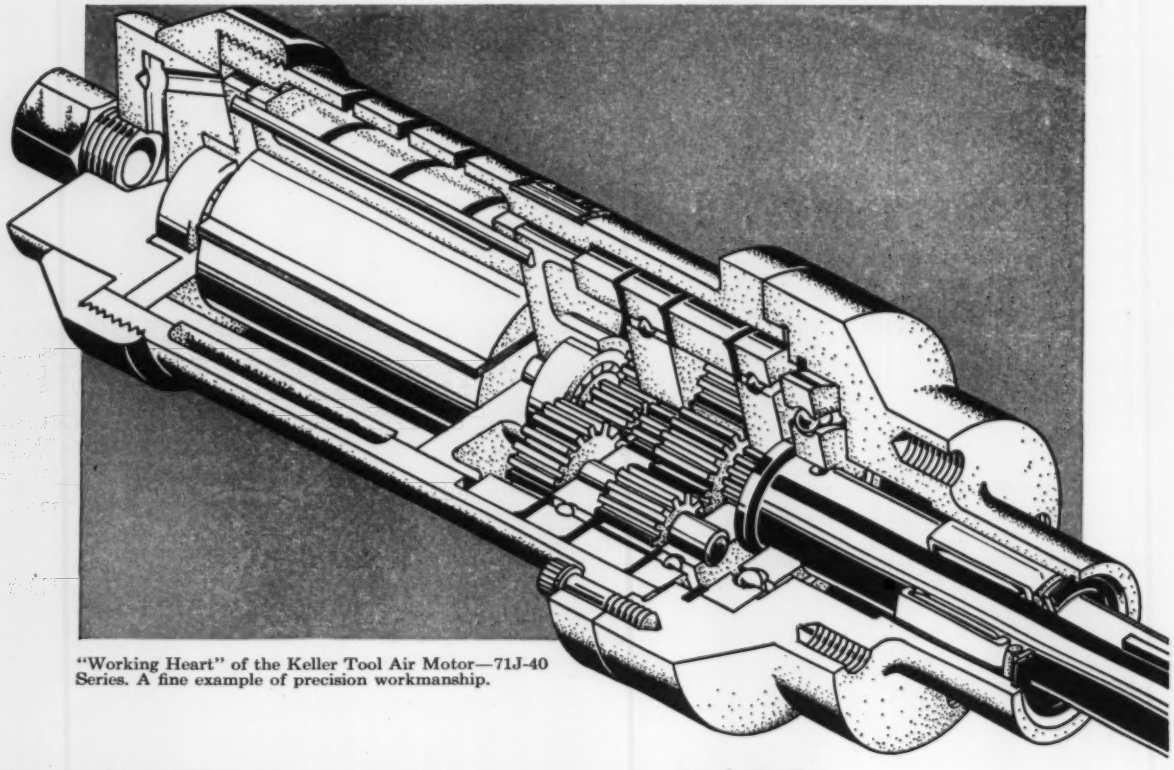
Amweld, with its special ability to form, weld, size and machine rings, circular weldments and components, is geared to the manufacture of such complex parts.

Do you have a component assembly problem? If so, contact the Industrial Products Division of The American Welding & Manufacturing Co. today! They will be pleased to help you.

THE AMERICAN WELDING & MANUFACTURING CO.
130 DIETZ ROAD • WARREN, OHIO

AMERICAN WELDING

Gardner-Denver . . . Serving the World's Basic Industries



"Working Heart" of the Keller Tool Air Motor—71J-40 Series. A fine example of precision workmanship.

Look inside before you decide

Air motors look pretty much alike—from the outside. It's the inside "working heart" that decides how long they give satisfactory service without frequent trips to the repair shop. There's work for a Keller Tool Air Motor in many design applications.

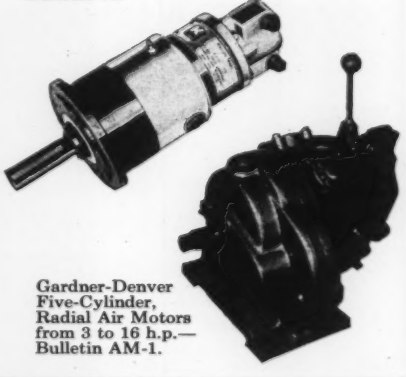
HERE ARE REASONS WHY 71J-40 IS A LEADER

- **Compact . . . Powerful.** One full horsepower in a vane-type air motor less than 13 inches long.
- **Quick starts . . . Quick stops**—unlike an electric motor. Stands up under this type of usage.
- **Non-sparking.** Air power is safe . . . eliminates hazard present when using other types of motors.
- **Will not burn out** . . . because there is nothing to burn out. Can run to a stall without damage.
- **Heavy-duty construction**—to stand up under heavy loads. Heavy cast aluminum gear case and motor housing.

Send for Bulletin 71 for specifications.

Other leaders in the Keller Tool and Gardner-Denver Air Motor Family

Keller Tool Axial Piston Air Motor—70A Series from ½ to 2¾ h.p.—Bulletin 70.



Gardner-Denver Five-Cylinder, Radial Air Motors from 3 to 16 h.p.—Bulletin AM-1.

GARDNER-DENVER

KELLER TOOL division, Grand Haven, Michigan

THE QUALITY LEADER IN COMPRESSORS, PUMPS, ROCK DRILLS AND AIR TOOLS FOR CONSTRUCTION, MINING, PETROLEUM AND GENERAL INDUSTRY

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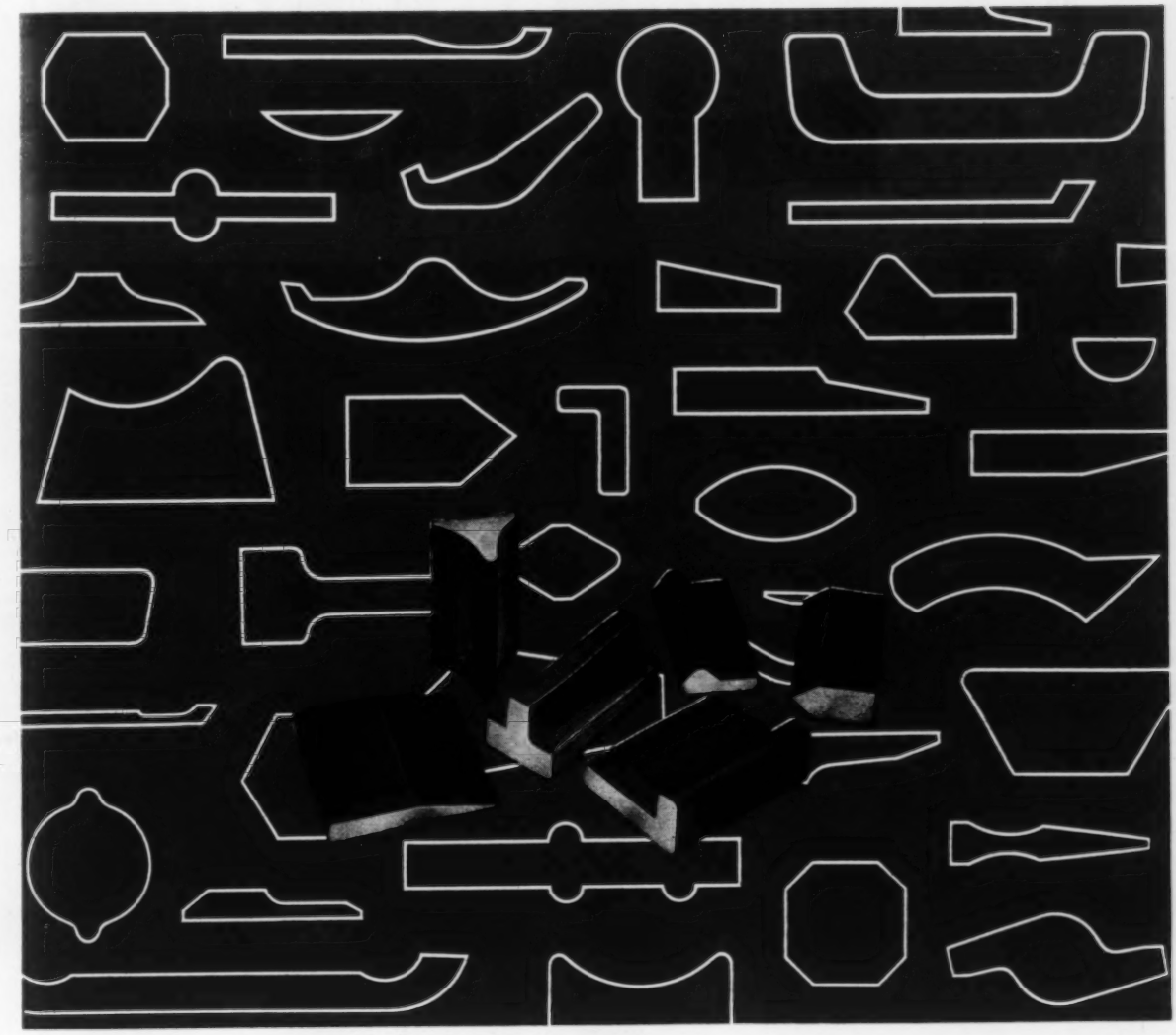


Crucible special shapes

for better alloy steel parts at lower cost . . .

If you're machining intricate sections from solid bars—or using expensive forgings—stop! Choose instead, a *Crucible special shape* that approximates the finished part. *Crucible special shapes* eliminate rough-machining operations . . . reduce scrap losses.

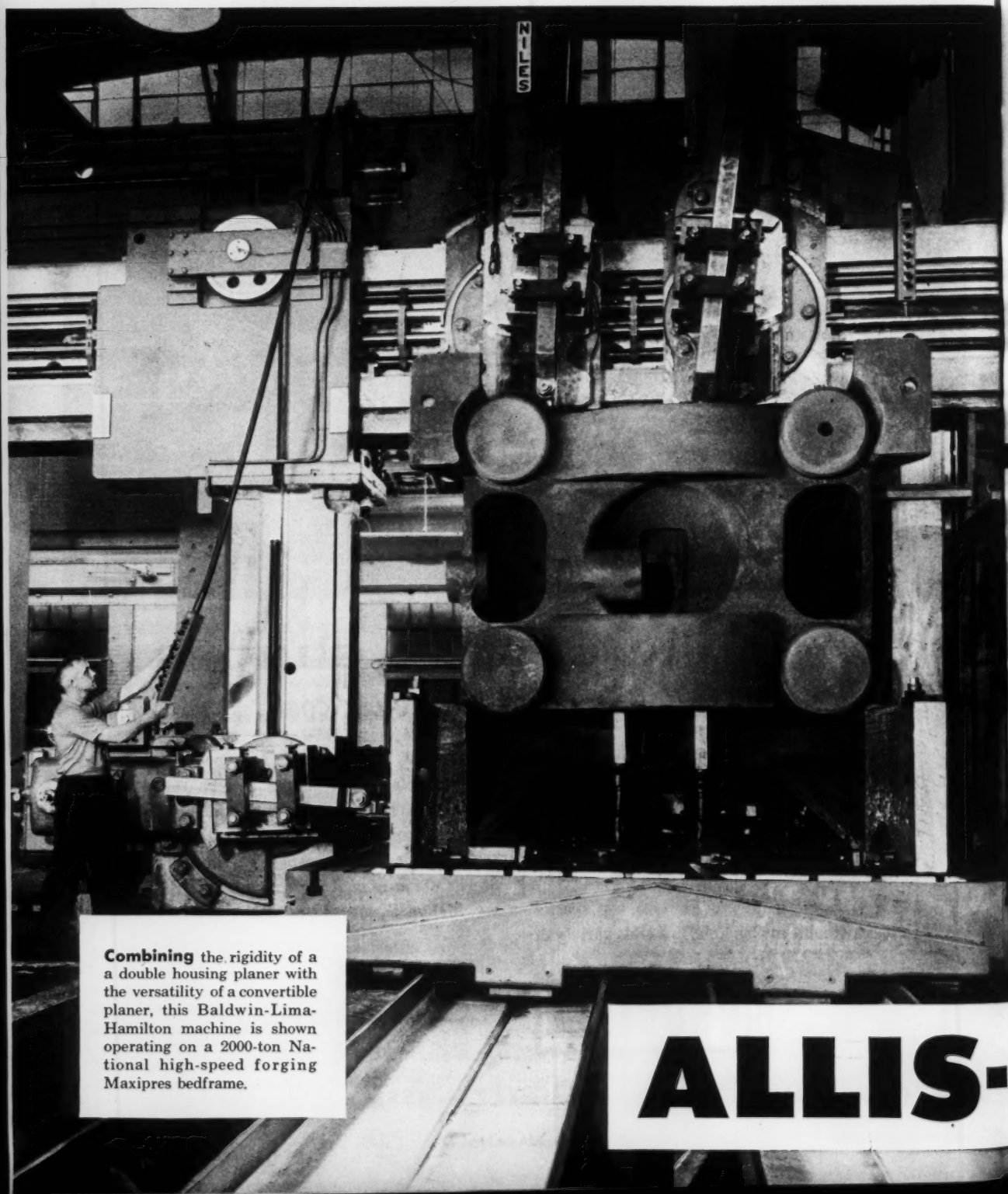
There's practically no limit to the *special shapes* available at Crucible, in a wide variety of alloy steels. Rolls for over 400 special shapes are available—other shapes can be rolled to your specifications. Your local Crucible representative can give you the whole story of how *special shapes* can cut costs—save time. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

Allis-Chalmers DC MOTOR and

Drive Giant



Combining the rigidity of a a double housing planer with the versatility of a convertible planer, this Baldwin-Lima-Hamilton machine is shown operating on a 2000-ton National high-speed forging Maxipres bedframe.

ALLIS-

CONTROL...

New Planer

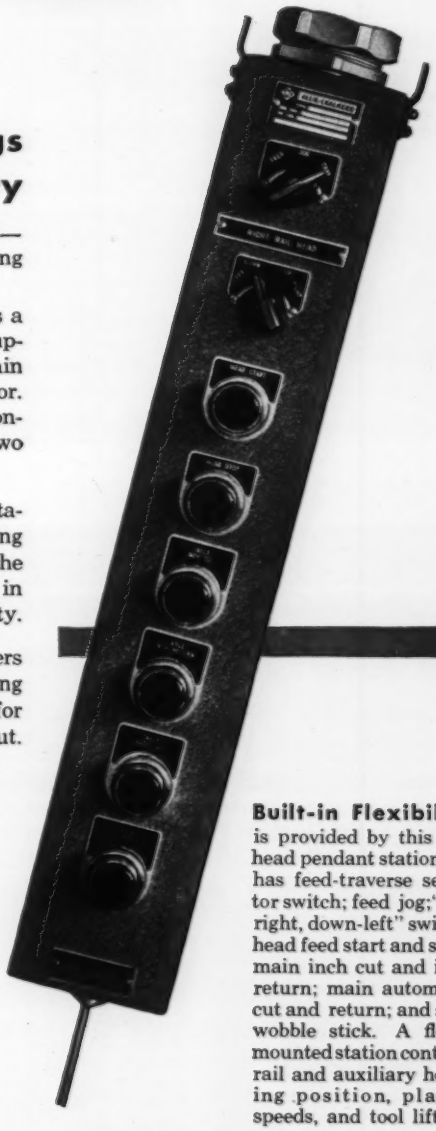
Baldwin-Lima-Hamilton NILES Planer Handles Flatcar-Size Castings in One Setup at National Machinery

Reduced machining time . . . single setup . . . one-man control — all are advantages of this huge planer which handles any casting within the size dimensions of a railroad flatcar shipment.

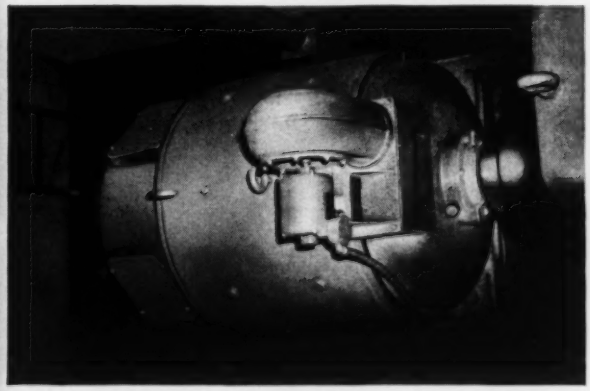
Giving the giant machine maximum flexibility and speed is a specially engineered combination of Allis-Chalmers motors, supporting motor-generator set, *Regulex* exciter, and control. Main power is supplied by a 100-hp, variable-voltage reversing motor. This motor and the auxiliary ac motors are coordinated by controls which can be operated from several locations, including two pendant stations.

Single-Handed Positioning — The pendant control stations and other stations permit the operator to position for planing and make all adjustments without help. From one location he may adjust both the left-hand auxiliary housing and planing, in addition to other functions. This gives the machine great flexibility.

On-the-Job Insurance — Every part of the Allis-Chalmers drive motors, from long-lasting field coils to thorough ventilating system, is built to eliminate costly shutdowns. It's designed for heavy duty . . . handles extra-tough cuts with no chance of burnout.



Built-in Flexibility is provided by this rail head pendant station. It has feed-traverse selector switch; feed jog; "up-right, down-left" switch; head feed start and stop; main inch cut and inch return; main automatic cut and return; and stop wobble stick. A floor-mounted station controls rail and auxiliary housing position, planer speeds, and tool lifting.



Sturdy Construction is a prime feature of this Allis-Chalmers 100-hp, dc drive motor. Located in a deep pit below the planer, its rigid design holds bearing alignment true — keeps grease in, foreign particles out.

There's a right combination of Allis-Chalmers motors and control for your application, too. Contact your nearby Allis-Chalmers sales office or write Allis-Chalmers, General Products Division, Milwaukee 1, Wis.

CHALMERS

A-C ALLIS-CHALMERS

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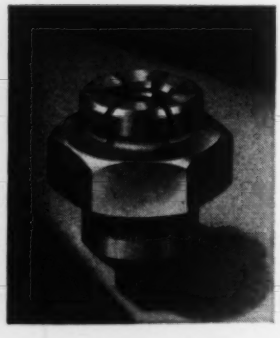
A-5039

How FLEXLOC clinch nuts save production time



If you are building assemblies of thin-section materials, you can make secure bolted connections with FLEXLOC clinch nuts. Use them instead of cage nuts, anchor nuts and weld nuts. They are easy to install—no riveting or welding is required.

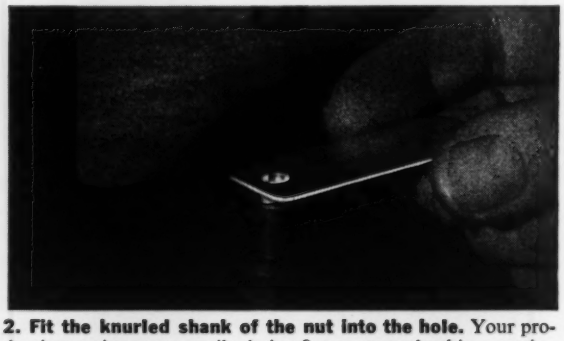
When you design with 1-piece, all-metal FLEXLOC clinch nuts, you simplify production operations by eliminating complicated nut-and-lockwasher assemblies. And the nuts cannot fall off or get lost during maintenance operations.

When you thread in a screw, the FLEXLOC locks it wherever wrenching stops (as soon as 1½ screw threads or more project through the locking section). Locking action is positive and dependable. No matter how many times your product must be reassembled during maintenance or repair, the FLEXLOC holds securely every time. Its locking life is virtually unlimited. It cannot be loosened by vibration.

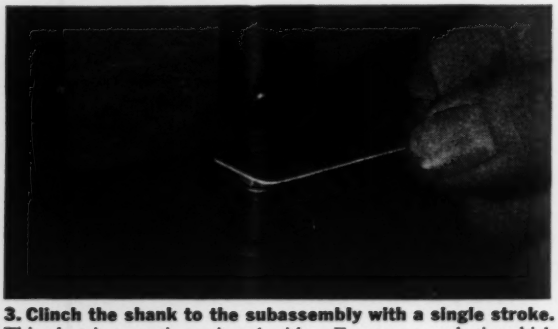
Standard FLEXLOC self-locking clinch nuts come in sizes #4 through ¼ in., for use in materials from 1/32 to 3/16 in. thick. They are made in alloy steel, stainless steel, brass and aluminum. FLEXLOC clinch nuts and clinching tools are available through your authorized industrial distributor. Call him today. Write us for complete specifications, or for information about your special locknut problem. Flexloc Locknut Division, STANDARD PRESSED STEEL CO., Jenkintown 18, Pa.

It's easy to install a FLEXLOC clinch nut

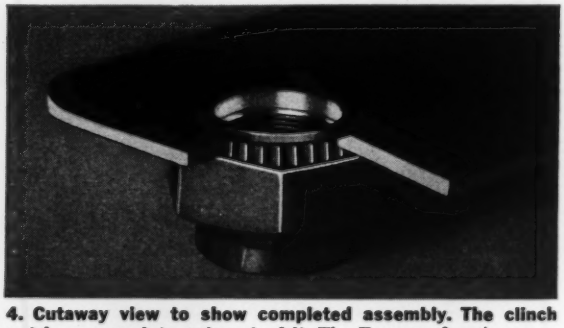
1. Hole in your subassembly accommodates the knurled shank of the FLEXLOC. The holding fixture is fitted with an inexpensive FLEXLOC dolly tip.



2. Fit the knurled shank of the nut into the hole. Your production engineers can easily design fixtures to make this operation completely automatic.



3. Clinch the shank to the subassembly with a single stroke. This electric press is equipped with a FLEXLOC punch tip which also can be used with an ordinary hammer.



4. Cutaway view to show completed assembly. The clinch nut is now an integral part of it. The FLEXLOC functions as a tapped hole—one that will lock a screw securely in place.

FLEXLOC locknuts are sold through authorized industrial distributors

STANDARD PRESSED STEEL CO.

FLEXLOC® LOCKNUT DIVISION SPS

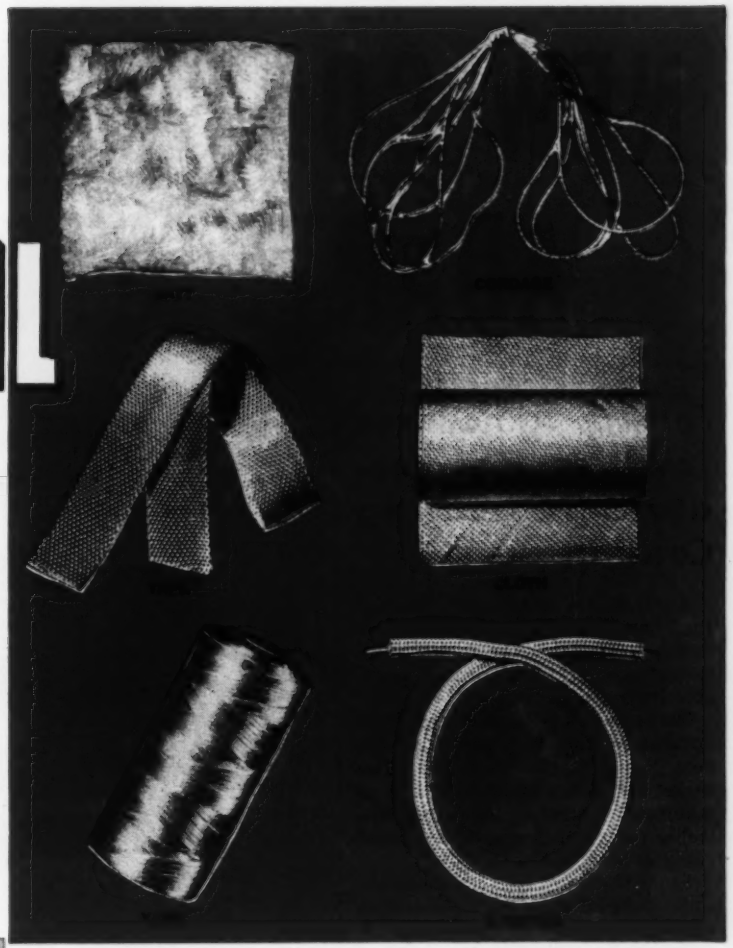
JENKINTOWN PENNSYLVANIA

Circle 538 on page 19

where can you use REFRASIL

2000°-3000° F. High Temperature Insulation

...it may be the special insulation you've been looking for!



REFRASIL PROPERTIES:

- Chemical resistance of pure silica
- Resists temperatures up to 3000°F. under certain conditions
- Low Thermal conductivity
- Fiber diameter .00020—.00040 in.
- Specific heat .19
- Thickness .14—.15 in.
- Surface density .05 lb./sq. ft.

REFRASIL USES:

- 2000°F. continuous high temp. insulation
- Filtration of corrosive materials
- Removable, insulating blankets
- REFRASIL and plastic laminates
- Thermocouple wire insulation
- Electric muffle furnaces
- Laboratory heating mantles

REFRASIL INSULATING BLANKETS:

"WRAP-AROUND"

"PRE-FORMED"

WHAT IS REFRASIL? REFRASIL is a highly efficient fibrous silica insulation material, extremely light in weight and bulk and made in a variety of physical forms.

REFRASIL has proven its high temperature insulation ability in millions of hours of jet aircraft operation. It is fast becoming an important industrial insulation for critical and extreme temperature applications from −300°F. cold to +3000°F. heat. Despite relatively high initial cost, REFRASIL is economical when restricted to special high temperature uses where ordinary insulation materials fail.

If you need an efficient, lightweight 2000°-3000° insulating material in bulk fiber or any of the physical forms shown, REFRASIL may be your best answer. For your *special* high temperature insulation problems, our research and development engineers are only a phone call away. Call or write for complete engineering information and free samples of REFRASIL, for your own testing.

• FREE NEW CHART!

First of a Series, this new High Temperature Insulation Chart contains helpful information on insulation for temperature ranges from −300° to +3000°F. Write for your free copy today!

HITCO

H. I. THOMPSON FIBER GLASS CO.
1733 Cordova Street · Los Angeles 7, California
REpublic 3-9161

HITCO HELPS INDUSTRY BEAT THE HEAT

WRITE OR CALL YOUR NEAREST REFRASIL REP.: EASTERN—Jack Trevlyn, 209 Thayer St., Ridley Park, Penn., WAshburn 8-5126 • MIDWEST—Burnie L. Weddle, 3219 W. 29th St., Indianapolis 22, Ind., HIckory 5-8685 • SOUTHWEST—Marshall Morris, 3515 Covert Ave., Fort Worth, Texas, WAlnut 3-8098 • Represented in Canada by RAILWAY & POWER ENGINEERING CORP.

Circle 539 on page 19

NEW CONTROLLER LINE ADAPTS 576 WAYS

Fenwal Announces Low-Cost Temperature Indicating Controllers

ASHLAND, MASS. — Fenwal Inc., has announced here that tailor-made, accurate, low-cost temperature indicating controllers are now available from stock.

Tailor-mades from stock are made possible by the development of the new Fenwal Series 541 line. The Series 541 is a standardized line of matched temperature indicating controller parts which can be combined easily in 576 ways.

From these possible combinations come perfect solutions to countless temperature control problems. A prospective user lists the characteristics of the ideal temperature indicating controller for his particular operation, and Fenwal assembles an instrument with those characteristics from parts in stock.

No matter what combination is chosen, the result is a rugged, accurate, compact and easily maintained unit in a shock-proof, splash-proof, dust-proof housing. The housing is available in colors to match any equipment in which it may be installed.

Installation and calibration are so simple that instrument technicians and laboratory procedures are unnecessary. And, after installation, all normal temperature adjustments are external.

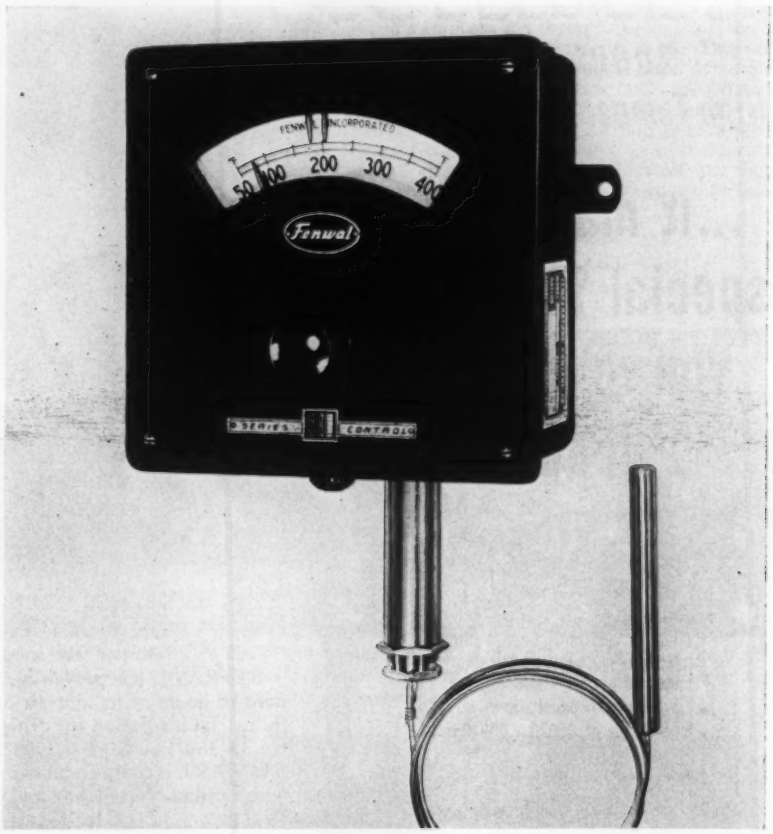
No matter what combination is chosen, the resulting instrument is accurate to within one per cent of scale. The accuracy is long lasting, with few moving parts and no internal gears. Simplicity of design brings the wear factor close to zero.

Series 541 offers single or double circuit control. There is a choice of four different long-life snap switches, with ratings up to 20 amps, 250 volts, A.C. These switches, singly or in combination, can provide a wide variety of operating characteristics.

Three stainless steel bulb types are available at no increase in price to meet space or process requirements. Capillaries and bulbs are corrosion-proof. Capillaries are swivel-mounted to protect them from breakage.

There is a choice of three temperature ranges: −150° to 200°F, 50° to 400°F, or 50° to 700°F, or their centigrade equivalents. Special ranges are available on request.

The control mechanism may be subjected to temperatures up to 150°F, and is ambient compensated from 50° to 150°F.



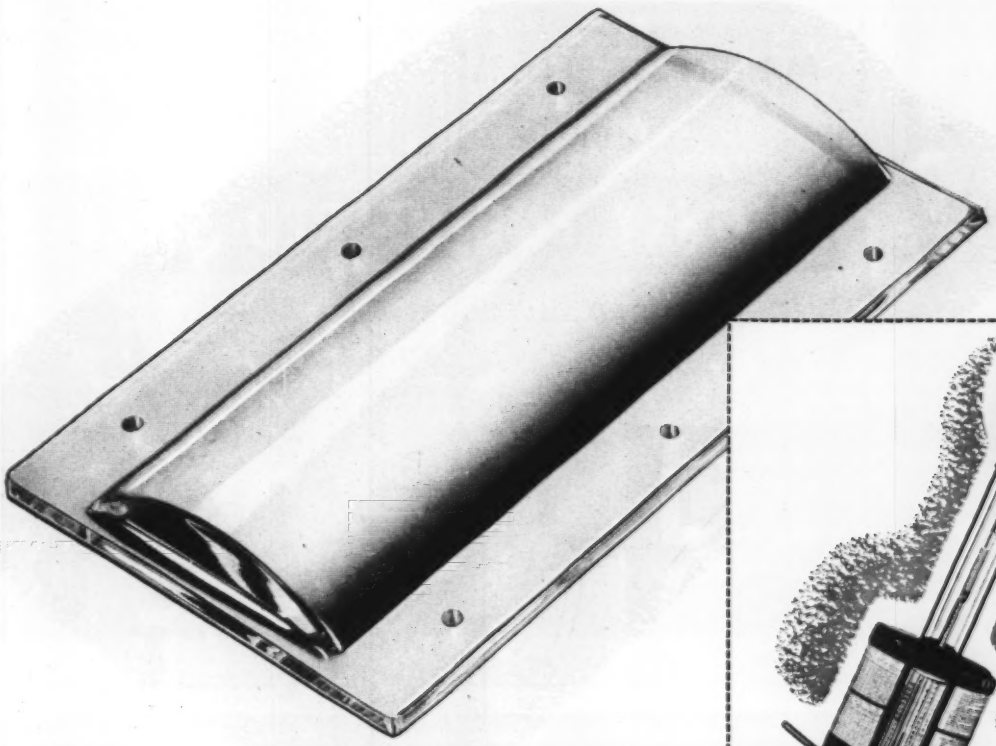
One of Fenwal's new Series 541, bulb-and-capillary controllers. Photo shows dual circuit model which has two snap switches, each with a setpoint indicator, that actuate two separate circuits at the pre-set temperatures.

Write to Fenwal Incorporated, 1911 Pleasant Street, Ashland, Mass. Describe the tailor-made temperature indicating controller that would fit your operation perfectly. Chances are excellent that the tailor-made can be yours — at savings never before possible.

Fenwal

CONTROLS TEMPERATURE
. . . PRECISELY

Circle 540 on page 19



A custom molded product of Sylvania's 4-way service

High quality custom molding to meet critical parts problems, such as the "magic eye", is an important part of Sylvania's *four-way* service to designers.

Sylvania's Parts Division also offers you complete facilities for metal parts ranging from wire forms to deep drawn eyelets; plated and clad specialty wires; and special components.

For the complete story, write for the Portfolio of 4-way Service to Designers.

Plexiglass Magnifier Lens calls for close tolerances

Key feature in new anti-freeze tester made by E. Edelmann & Co. is the "magic eye" magnifier lens which provides easy readings under all lighting and weather conditions.

It took a qualified molder though, to maintain the high level of quality dictated by this part's function. It had to be kept free from bubbles and blemishes. Mounting hole tolerances were held to ±.003. Flat surface was controlled to within .010 T.I.R. and the part was annealed to insure flatness over an extended shelf life.

The "magic eye" was molded of Rohm & Hass methyl methacrylate on a 12-oz. Reed-Prentice press.

SYLVANIA PARTS DIVISION

Sylvania Electric Products Inc., Parts Division, Warren, Pennsylvania

SPECIAL WIRE · METAL STAMPINGS · MOLDED PLASTIC · ELECTRONIC COMPONENTS

4-way service from one source

Circle 541 on page 19

"Custom-Engineered"

AXLE SHAFTS

for every application...

From bomber to baby-buggy, our 35 years of expert engineering skills can help you improve *your* product performance!

Add to these, our large-scale metal-working facilities, equipped with every modern means to make the *world's finest shafts!* Our new shot peening process guarantees finished shafts *proved up to 5 times tougher* than unpeened shafts! We will be happy to work with you on any problem that turns on a shaft.

Call on U. S. AXLE for every type of Special Shaft

- Drive Shafts
- Idler Shafts
- Gear Shafts
- Clutch Shafts
- Cam Shafts
- Transmission Shafts

..THE WORLD TURNS ON U. S. AXLES"

This illustrated folder will show you why U. S. AXLE is your best source for precision-made special shafts. Write for your copy today.

For a prompt quotation on a U S. "Custom-Engineered" Shaft to meet your needs, send us your blueprints and specifications.

THE US AXLE COMPANY, INC.
Since 1920 • Pottstown, Pennsylvania

MONEY-SAVING MAGIC IN THIS "HEEL AND TOE"

This Tinnerman fastener is modeled after your foot . . . there's a heel and toe . . . it slides easily into the holes punched in the metal, fiber, or plastic, even as your foot slides into a shoe. But it is much easier to put on than to take off!

The primary function of this SPEED NUT fastening principle is to provide a fast, easy-to-apply, low-cost, self-retaining fastener. Its snap-on attachment feature requires little skill and no welding or staking. Yet it assures positive retention for center panel or blind locations.

Tinnerman "heel-and-toe" fasteners can also have a wide variety of fastening features. The self-retaining heel-and-toe can be combined with the famous Tinnerman SPEED NUT impression. Or with a speedy cable clip . . . or a spring catch . . . a molding clip . . . a wire retainer . . . almost any fastening idea you require.

Tinnerman sales engineers are ready to make a SPEED NUT Analysis of your fastening requirements. Or you can write to us for details and engineering data. *Tinnerman Products, Inc., Box 6688, Dept. 12, Cleveland 1, Ohio.*

TINNERMAN
Speed Nuts®

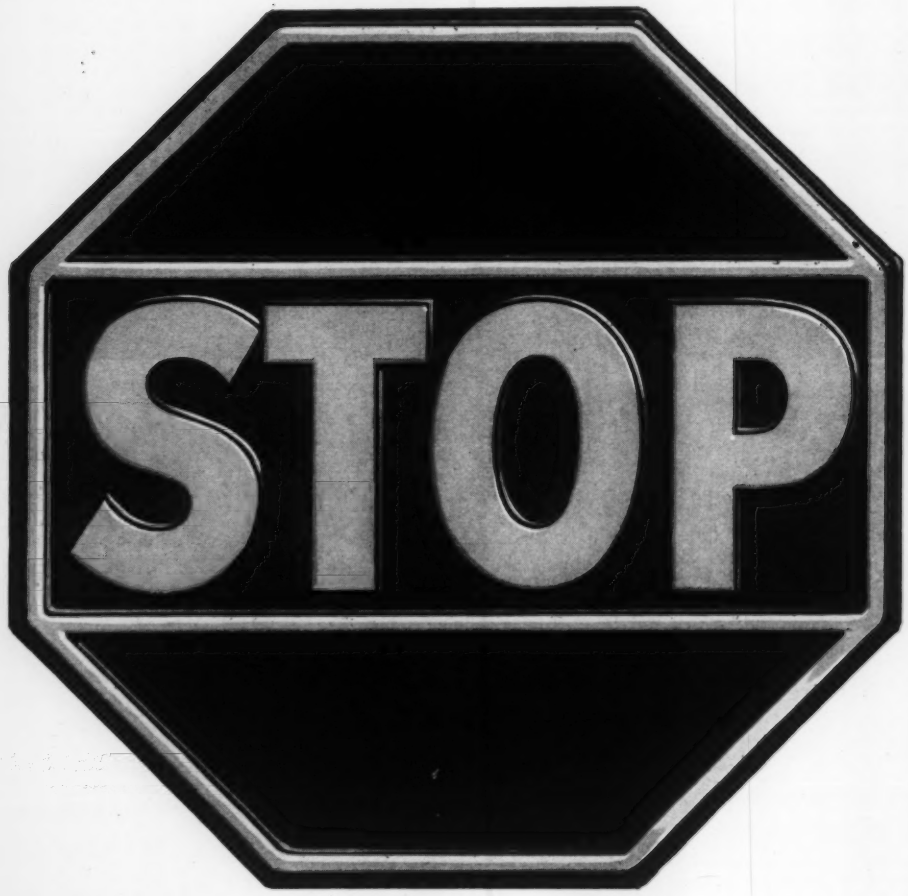
FASTEST THING IN FASTENINGS®

On dictating equipment, this SPEED CLIP® holds wires safely away from moving parts.

SPEED CLIPS secure molding on plastic sign, help manufacturer gain 48% assembly saving.

Assembly of TV tuning coil to chassis and servicing simplified with special SPEED CLIP.

Circle 543 on page 19



The drafting stage—not later—is the time to design-in oil seals!

Oil seals are precision products. They are designed to operate under a specific set of conditions. Change just one of those conditions—lubricant, shaft speed, temperature, even bearing position—and a different seal will almost always be needed.

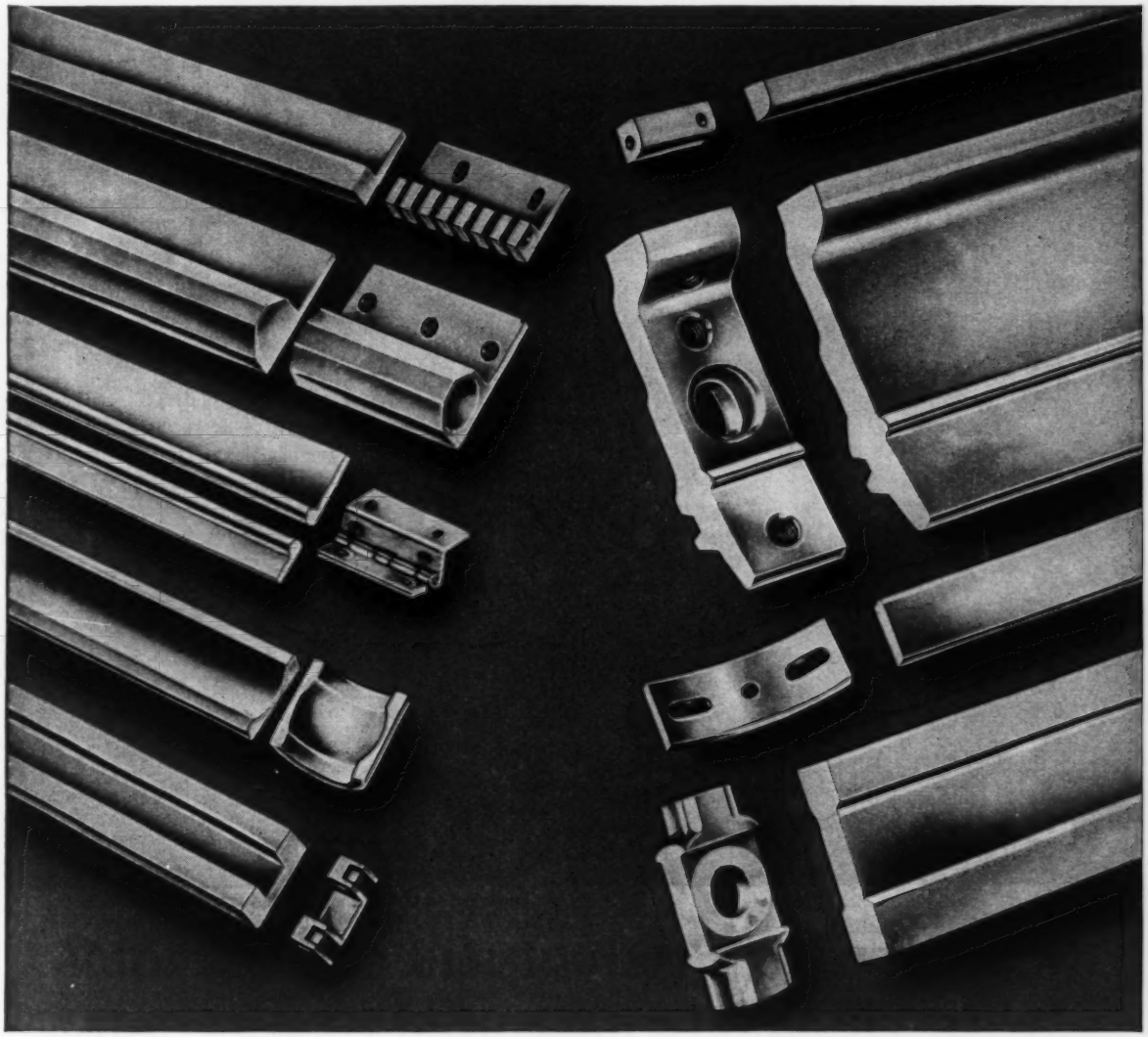
Why chance costly retooling or remanufacture? Specify the correct seal on the drawing-board. And when you do, get all the information there is on new seals, new lip compounds, and mechanical designs. Get it from your National Oil Seal Engineer. His counsel is complete, up-to-the-minute, and accurate. You couldn't buy better oil seal information, yet his help is yours for the asking.

Why "do it yourself?" Call the nearest National Oil Seal Engineer now.

NATIONAL SEAL
DIVISION, Federal-Mogul-Bower Bearings, Inc.
GENERAL OFFICES: Redwood City, California
PLANTS: Van Wert, Ohio and Redwood City, California

CHICAGO, ILL. . *Room 462, McCormick Building, HArrison 7-5163*
CLEVELAND, OHIO . *210 Heights Rockefeller Bldg., YEllowstone 2-2720*
DETROIT, MICH. . . . . *13836 Puritan Avenue, VErmont 6-1909*
INDIANAPOLIS, INDIANA . . *2802 North Delaware St., WAlnut 3-1535*
MILWAUKEE, WIS. . . *647 West Virginia Street, BRoadway 1-3234*
NEWARK, N. J. . . . . *1180 Raymond Blvd., MItchell 2-7586*

A SHORT CUT TO A FINISHED PRODUCT



REDUCE YOUR MACHINING OPERATIONS, REDUCE SCRAP

get a superior wrought metal product with Anaconda extruded shapes

Cost-paring possibilities unlimited: In few areas can imagination and ingenuity pay off so handsomely as when applied to the use of extruded shapes. Visualize your finished parts as cross-sectional pieces cut from a long extruded shape.

Costs come down, quality goes up: Extruded metal is *wrought* metal—tough, dense-grained, smooth-surfaced, and easy to machine. When you switch from cast parts, you eliminate rejects due to pits and porosity; you reduce machining, scrap . . . and finishing time.

A manufacturer of hosiery knitting machines, for example, found he saved from 25-30% over cast brass. He makes 420 components from 12 different ANACONDA Extruded and Drawn Brass Shapes. He also gets the superior precision, balance, and long-wearing and bearing qualities in these parts, which must operate at high speeds.

Metals: Extruded shapes are available in copper, brass, bronze, and special copper alloys—in long mill lengths suitable for feeding into turret lathes or automatic screw machines.

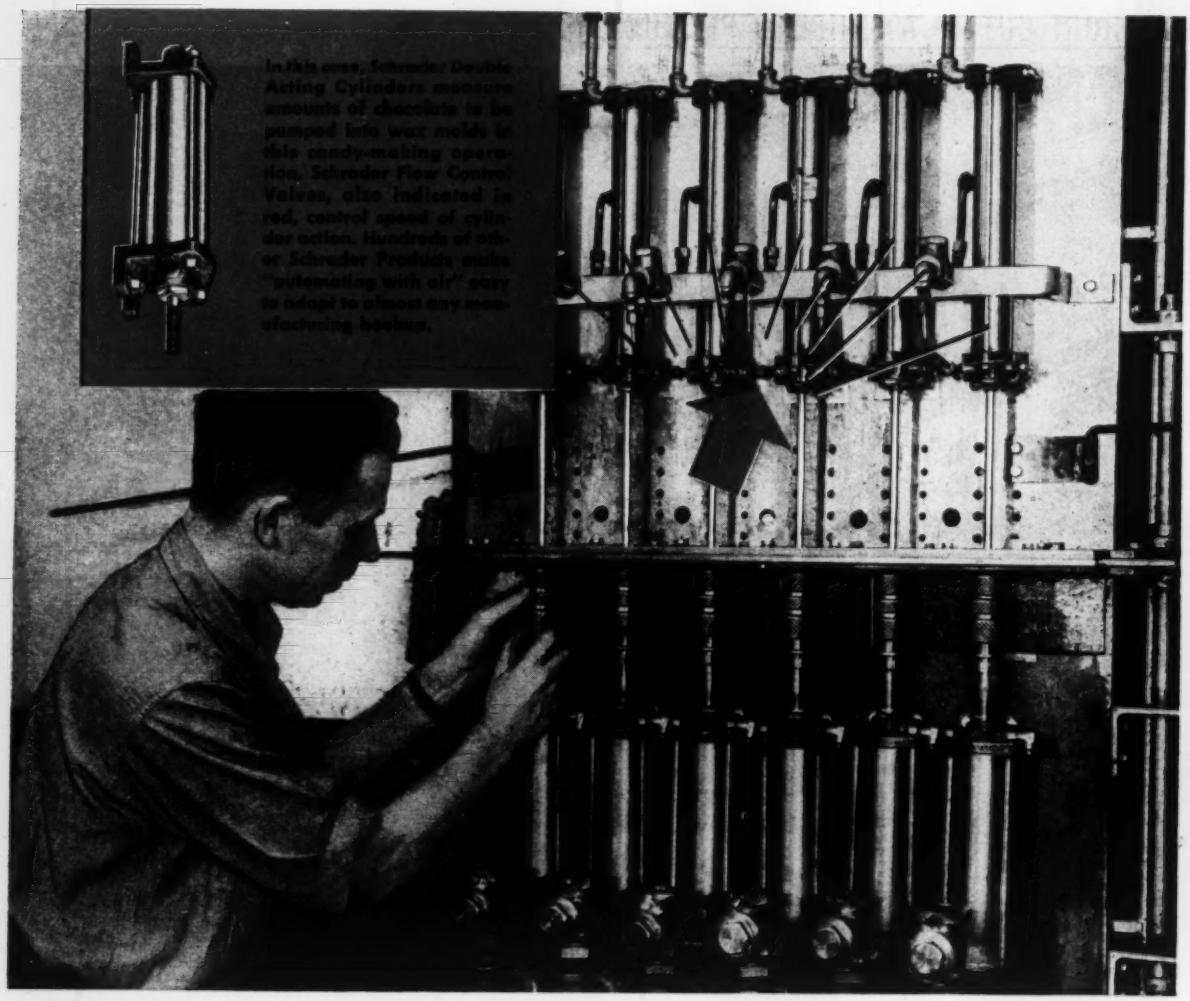
Our experience at your service: The American Brass Company pioneered in extruded shapes. The accumulated experience of the organization, its wide selection of dies, may help you short-cut production and save money.

We'll be glad to make suggestions based on your sketch or sample. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

5589

ANACONDA®
EXTRUDED SHAPES

Circle 545 on page 19


In this case, Schrader Double-Acting Cylinders measure amounts of chocolate to be pumped into wax molds in this candy-making operation. Schrader Flow Control Valves, also indicated in red, control speed of cylinder action. Hundreds of other Schrader Products make "automating with air" easy to adapt to almost any manufacturing hookup.

Schrader Air Products fill candy molds with chocolate measured to ± 1 gram

Problem: To mass-produce candy figurines, filled solid with chocolate—a tricky sweet to handle. **Solution:** One Buffalo company uses a battery of Schrader Air Cylinders which measure the chocolate to within one gram, and precisely, neatly, swiftly fill the figures.

The uses of Schrader Air Products are limited only by producers' imaginations. Versatile, safe, simple and fast, the hundreds of different units in Schrader's complete line can be employed singly or in combinations to perform automatic operations. And wherever air is used, economies are gained that increase its efficiency even more.

Think air whenever you think automation—in holding or positioning work, moving scraps or chips, or synchronizing actions. Upon request, Schrader engineers will assist you in planning for your best use of air, and in selecting the products best suited to your applications. Outline your problem and we'll be glad to help. Or send for the latest informative booklets which show Schrader Air Products that will simplify your production.

Schrader®
ESTABLISHED IN 1844

A. SCHRADER'S SON
Division of Scovill Manufacturing Company, Incorporated
476 Vanderbilt Avenue, Brooklyn 38, N. Y.

FIRST NAME IN THE USE OF AIR
FOR INDUSTRIAL PRODUCTION AND CONTROL

Circle 546 on page 19

AVOID the **HIGH COST** and difficulty of fabricating long, hard & straight parts by conventional methods . . .

THOMSON

60 Case

hardened and ground

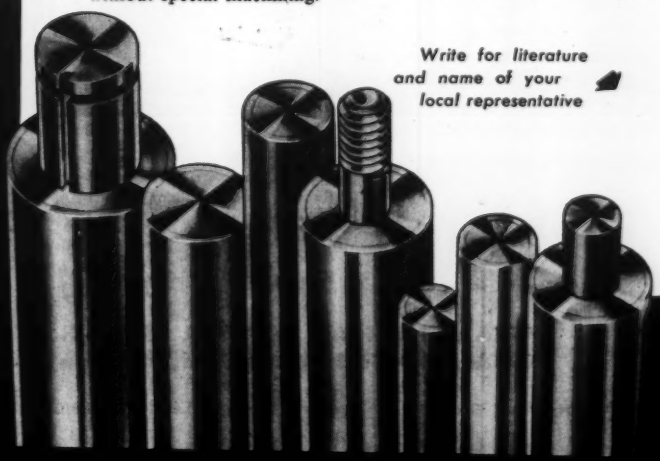
SHAFTS, ROLLS, GUIDE RODS and other long-round parts

60 Case is the result of over ten years of experimental work and production experience with hardened and ground shafts which are a requirement for BALL BUSHINGS, the Linear Ball Bearing manufactured by Thomson Industries, Inc.

The special techniques and equipment that have been developed enable high production rates and low handling costs. This permits big savings over conventional methods which are plagued with erratic warpage, straightening and resultant grinding problems. Finished *60 Case* parts frequently cost less than the scrap losses that result from conventional methods.

60 Case material has a surface hardness close to 60 on the Rockwell C scale which is essential to resist wear.

Long lengths of material ranging in diameter from ¼" to 4" are stocked to enable prompt shipment of *60 Case* parts, with or without special machining.



Write for literature and name of your local representative

ADVANTAGES of *60 Case*

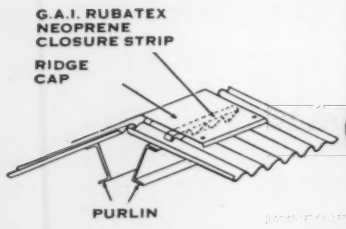
- COST REDUCTION
- HARD BEARING SURFACE
- ACCURATE DIAMETERS
- GROUND FINISH
- STRAIGHT PARTS
- DELIVERY FROM STOCK
- ADDED STRENGTH
- UNIFORM HIGH QUALITY

TYPICAL *60 Case* PARTS

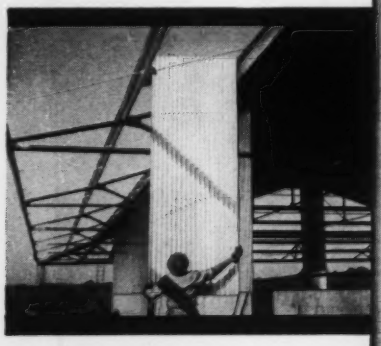
GUIDE RODS, SHAFTING, ROLLS, TRAVERSE RAILS, PISTON RODS, ARBORS, LEADER PINS, TIE RODS, KING PINS, AXLES, CONTROL RODS, GUIDE POSTS, MANDRELS, BEARING ROLLERS, SPINDLES

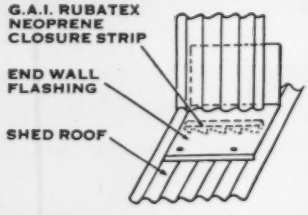
THOMSON INDUSTRIES, Inc.
Dept. C5, Manhasset, New York

Circle 547 on page 19

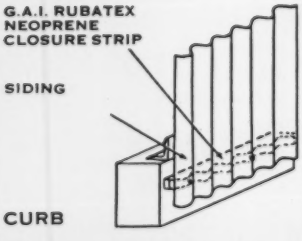


RIDGE

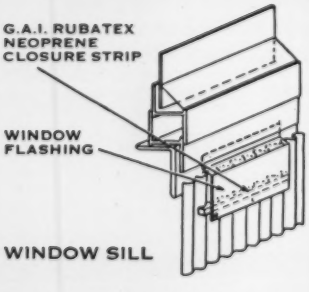




END WALL



CURB



WINDOW SILL

doing unusual jobs unusually well for 20 years

Rubatex is on the materials approved list of REYNOLDS METALS as neoprene closure strips for their Aluminum Industrial Corrugated Roofing and Siding installations. Die-cut to fit corrugations, Rubatex's unique closed cellular structure forms a snug, positive air-, water- and dust-proof seal . . . under aprons of ridge roll . . . with flashing sections at roof junctions, sidewalls or end walls . . . to close bottom of lower course of siding sheets and with flashing sections at window and door openings.

Speaks many industrial languages

For 20 years manufacturers (top ranking companies as well as smaller concerns) in the automotive, aircraft, electrical appliance, construction, instrument, packaging, shoe, sporting goods, consumer household products and general industries have used Rubatex—for effective gasketing, sealing, cushioning, sound deadening, vibration isolation and packaging jobs. Tested proof that these companies find Rubatex offers advantages no other soft rubber materials can PLUS better performance cheaper. Write us for details on how Rubatex can help your product or application.

G.A.I. RUBATEX

PIONEER MANUFACTURER OF CLOSED CELLULAR RUBBER

also manufacturers of:
Rubatex Insulation Hardboard
Rubatex Closed Cellular Vinyl
Rubatex-Crepe
Rubatex Softee-Crepe
Rubatex Vinyl Foam
Rubatex Plastic Seine Floats

GREAT AMERICAN INDUSTRIES, INC.
RUBATEX DIVISION, Bedford, Virginia

Circle 548 on page 19

A message to the *Career-Conscious Engineer:*

Ready to change jobs?

Perhaps you are not receiving a salary commensurate with your work.

Perhaps you are dissatisfied with your rate of promotion.

Perhaps you do not have enough scope for your ability in your present job.

Or perhaps you simply want to move to Southern California.

We invite you to consider the California Division of Lockheed Aircraft Corporation as the place to re-establish your career. For these reasons:

Promotional Opportunities are excellent because there are so many supervisory positions to be filled with 46 major projects in progress at Lockheed and because Lockheed is in an expanding development and production program.

You have more scope to show what you can do because Lockheed projects range across virtually the entire spectrum of aeronautical endeavor. You are not limited to one type of work because Lockheed is so diversified in projects. Moreover, Lockheed encourages and welcomes personal initiative.

You may receive a substantial increase in pay because Lockheed is extremely liberal in direct salary and in extra employee benefits, which actually increase the value of your position by an average of 14%. *Engineers' salaries have been raised 19% in the last three and one-half years.*

Positions are open at all levels for engineers in fields of: Aerodynamics – Design – Electronics, with emphasis on systems and antenna design – Flight Test Engineering, particularly in instrumentation – Math. Analysis – Operations Research – Structures – Thermodynamics – Weight.

Space prevents us from listing all the reasons we believe you will find significant. There are many others. But if our brief remarks make sense to you, write us and we can explore your opportunities at Lockheed through personal interview or phone. The brief resumé below is simply for your convenience in contacting us.

ADVANCED EDUCATION PROGRAM FOR ENGINEERS

You can expand your technical knowledge and achieve advanced degrees through a variety of Lockheed-sponsored university programs that cost you little or nothing.

TO ENGINEERS WHO LACK AIRCRAFT EXPERIENCE

Aircraft experience is not necessary to join Lockheed. It's your engineering training and experience that count. Lockheed trains you for aircraft engineering – at full pay.

Lockheed AIRCRAFT CORPORATION

California Division BURBANK **California**

E. W. Des Lauriers, Dept. CJ-39-11
Lockheed Aircraft Corporation
Burbank, California

Dear Sir: Please send me your brochure detailing life and work at Lockheed.

Name

If you are an engineer, please state your field of engineering

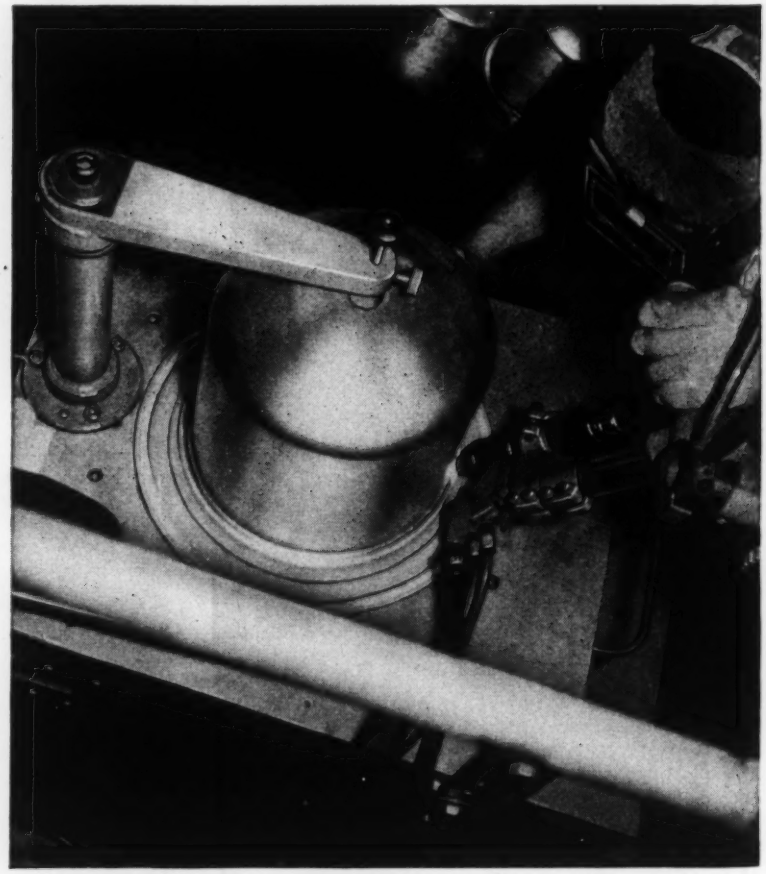
Home street address

City and State Home phone

Circle 549 on page 19

PRODUCTION *Zooms* 1000 PER CENT

with Mechanized HELIARC Welding



A HELIARC HW-13 torch is being used to weld a 1/8-in. aluminum radar cover.

A West Coast aircraft plant is using mechanized HELIARC welding to join the components of aluminum sealing covers for radar units—the "Seeing Eyes" of the Armed Services. Welding time has been cut from one hour and 10 minutes to only six minutes and the plant now turns out eleven covers in the same time it had formerly taken to produce one. Because the HELIARC welds are shielded from contamination by an inert gas, such as argon, they require no flux and are free from porosity and oxide inclusion. This results in fewer rejections and a minimum of finishing.

LINDE's team of welding processes—HELIARC, sigma, and UNIONMELT welding—can help you cut production costs and increase quality. Whatever your welding problem—one of LINDE's electric welding processes can do the job efficiently and economically. Call your local LINDE representative today for more information.

Linde Air Products Company
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
Offices in Other Principal Cities
In Canada: LINDE AIR PRODUCTS COMPANY
Division of Union Carbide Canada Limited, Toronto
(formerly Dominion Oxygen Company)

Linde Trade-Mark

†"Heliarc," "Unionmelt" and "Linde" are registered trade-marks of Union Carbide and Carbon Corporation.

Circle 550 on page 19

Pressur-Forming

ASSURES A BETTER FIT, GREATER STRENGTH, LONGER LIFE

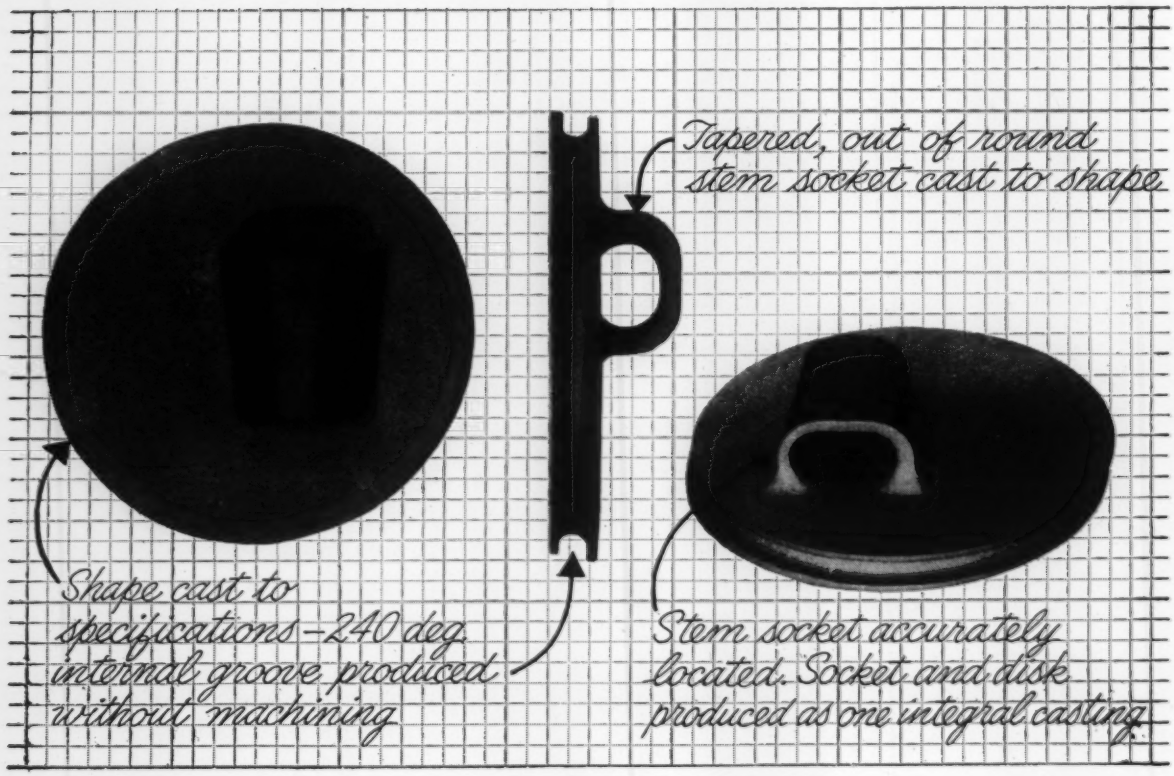
ALLEN originated the cold forging method of precision screw production. Today's advanced methods result in a combination of tremendous strength, fatigue resistance and precision.

Pressur-forming preserves the tough fibers of Allenoy steel continuous, uncut and concentrated where strength is needed most . . . conforming to the contours of head, socket and threads.

NOW WITH THE LEADER POINT Allen's exclusive unthreaded leader point makes starting easier and protects against cross threading or damage if the screw is accidentally knocked or dropped. Your Allen Distributor provides a "local warehouse" for Allen fasteners — plus a storehouse of fastening know-how. Call him for unbeatable service or write the factory direct for engineering information.

Allen 'pressur-formd' cap screws are standard stock items in sizes from No. 2 thru 1½ in. Flat Head Cap Screws, No. 4 thru ¾ in. Button Head Cap Screws are standard from No. 8 thru ⅝ in. N. C. threads. Many sizes are also standard in Stainless Steel, or in Allenoy steel with N. F. threads.

Circle 551 on page 19


Tapered, out of round stem socket cast to shape
Shape cast to specifications – 240 deg. internal groove produced without machining
Stem socket accurately located. Socket and disk produced as one integral casting

Investment-Cast in One Piece . . . 5 Secondary Operations Avoided

This intricate valve disk and stem socket were investment cast at a considerable saving in machining, assembling, and joining costs. The disk is produced in an odd shape and has a concave rim with a 240-degree groove. There is a tapered, out-of-round recess in the stem socket. The disk and socket were designed and produced as one integral casting.

The shape of the disk, vital to the proper functioning of the part, was cast to size. A contour machining operation would have been required to produce this shape by other methods. The groove in the rim of the disk, and the stem socket, were also cast to size . . . thus eliminating two more difficult machining operations.

An assembly operation, which would have required precision locating devices, was also avoided. The stem socket had to be accurately located . . . 0.225 in. from the centerline of the disk. This location was held to within plus or minus 0.005 in. on the finished part by the investment-casting method.

Reducing production costs by eliminating secondary operations is only one of the many advantages of HAYNES' precision-investment-casting process. For the full story call or write to any of the District Sales Offices listed below:

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

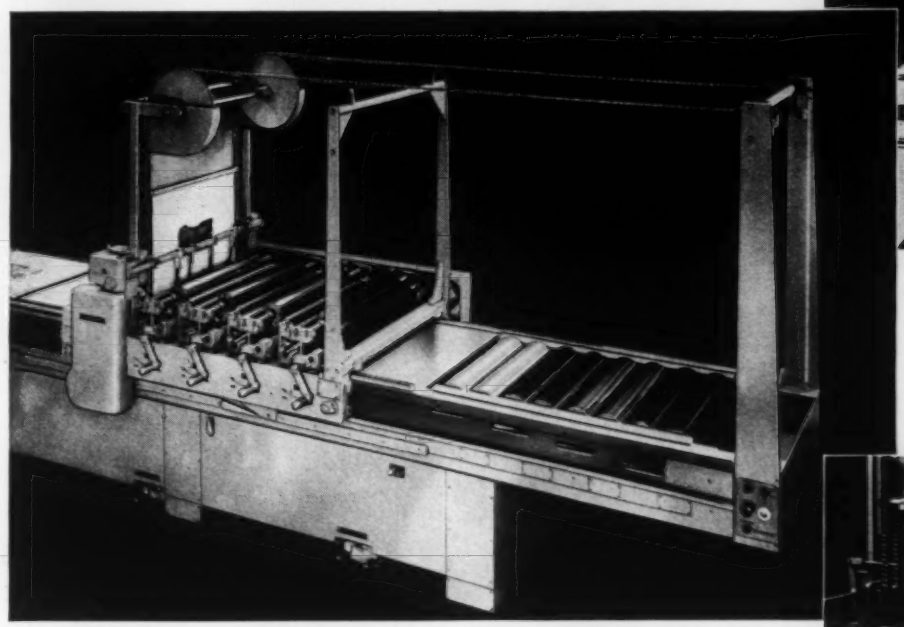
General Offices and Works, Kokomo, Indiana

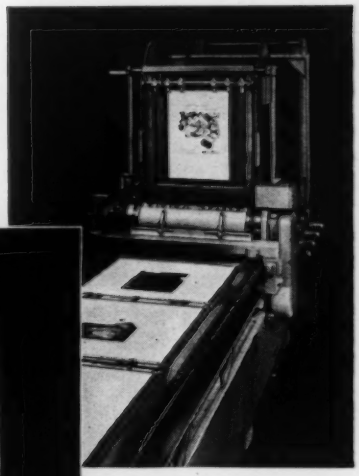
Sales Offices

Chicago • Cleveland • Detroit • Houston • Los Angeles • New York • San Francisco • Tulsa

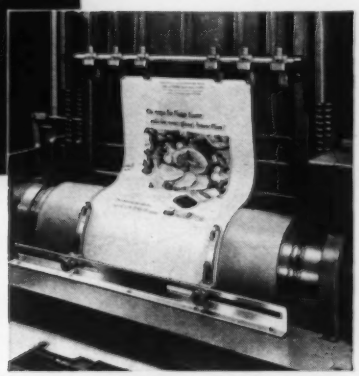
"Haynes" is a registered trade-mark of Union Carbide and Carbon Corporation

SPEED and PRECISION





◆ Vandercook 604 High Speed Four-Color Test Press equipped with Automatic Sheet Delivery. Diamond Roller Chains assure positive, *precision* operation.



◆ At the end of the printing stroke, grippers remove the finished proof and automatically return it to the operator's station.

WITH DIAMOND ROLLER CHAINS

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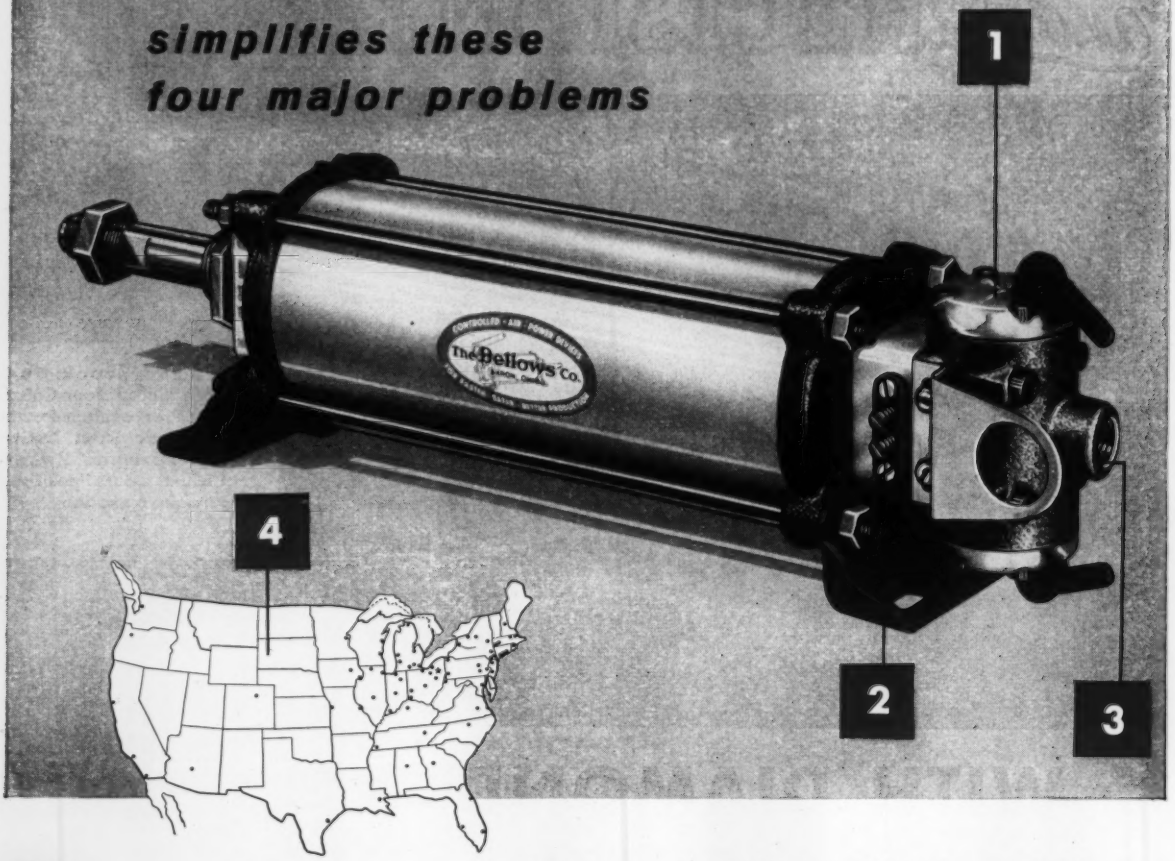
Circle 553 on page 19

THE Bellows AIR MOTOR

simplifies these four major problems



1 **Built-in electrically controlled directional valve, either 8 or 110 v., simplifies design problems.**

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Design, control, installation and service are problems every O.E.M. Design Engineer faces when selecting components for automation.

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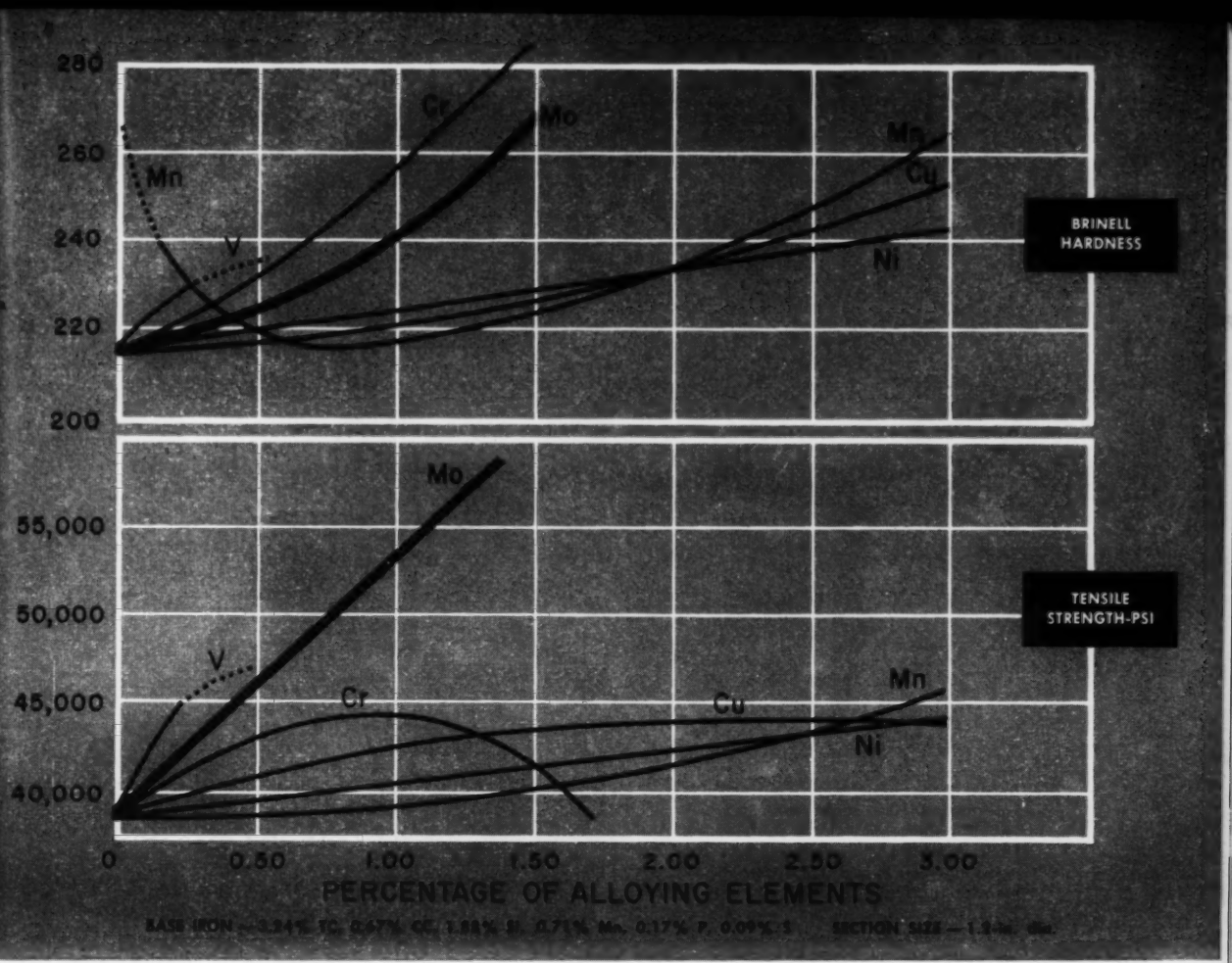
644B

Circle 554 on page 19



Note how additions of moly, up to 1.5%, produce proportional improvements in strength. And, with moly, hardness increases much more slowly. It means higher strengths can be used with less danger of impaired machinability.

each ½% Moly adds 7000 psi to strength of cast iron...

A little moly adds a lot of strength – for molybdenum increases strength more than any other common alloying element, with the exception of small vanadium additions. A rule of thumb is that fifty points of moly raise tensile strength 7000 psi. And without sacrificing toughness. Actually, moly improves toughness at least as much as strength.

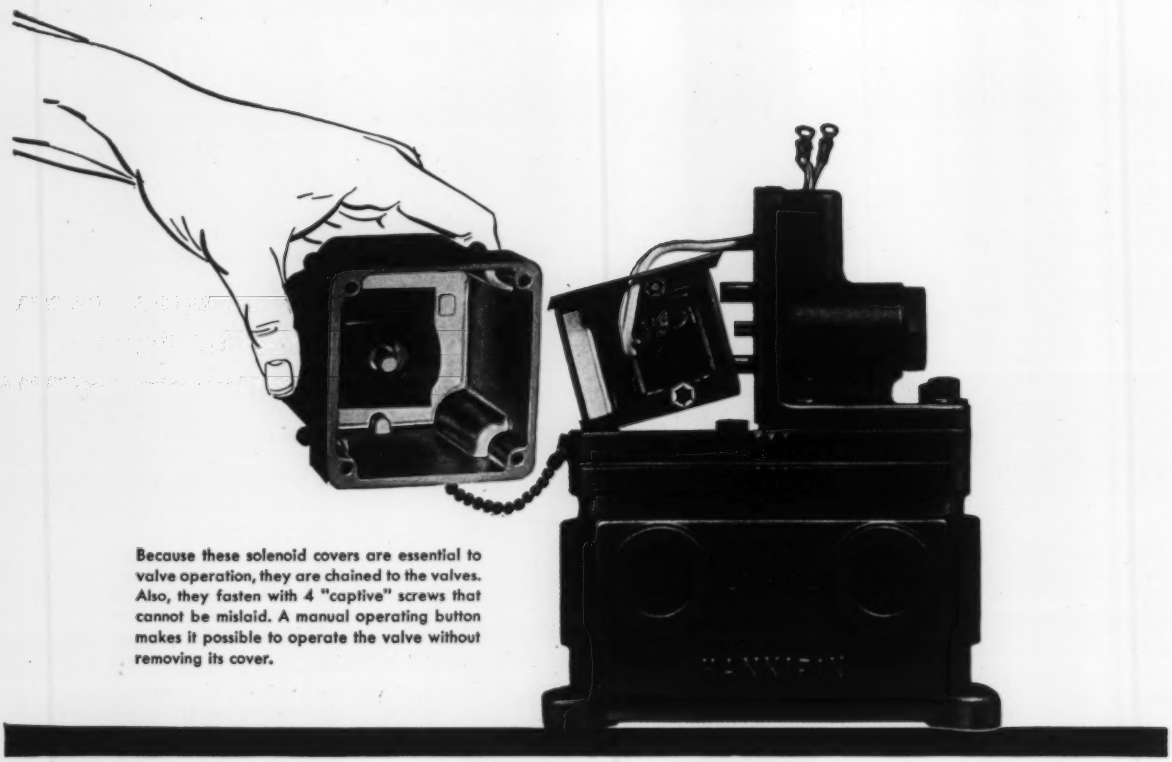
What's more, versatile moly aids in obtaining uniform response to heat treatment . . . and in producing machinable, growth-resistant castings. Moly is easy to use, too.

With most grades of cast iron, moly requires no change in the character of the charge, normal melting practice, or the base metal. And foundrymen like the fact that the small additions necessary may be made at the spout or in the ladle.

Write now for "Why Moly Iron". It's the full story of how and why moly adds strength faster than hardness, how it increases fatigue and torsional strength—in short why moly makes better cast iron. Climax Molybdenum Co., Dept. 11, 500 Fifth Avenue, New York 36, N. Y.

CLIMAX MOLYBDENUM

Circle 555 on page 19



Because these solenoid covers are essential to valve operation, they are chained to the valves. Also, they fasten with 4 "captive" screws that cannot be mislaid. A manual operating button makes it possible to operate the valve without removing its cover.

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These new valves, which conform to the latest J.I.C. recommendations, are part of the complete "P-M" Pilot-Master line. New heads with these new solenoid covers are offered on 2-way, 3-way and 4-way Pilot-Master Valves (air-operated). The smaller, direct-operated 3-way and 4-way valves in the "P-M" line have been redesigned to use the same new covers. This added feature is just another reason why it pays to standardize on Hannifin air control valves.

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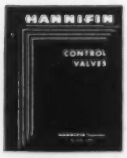
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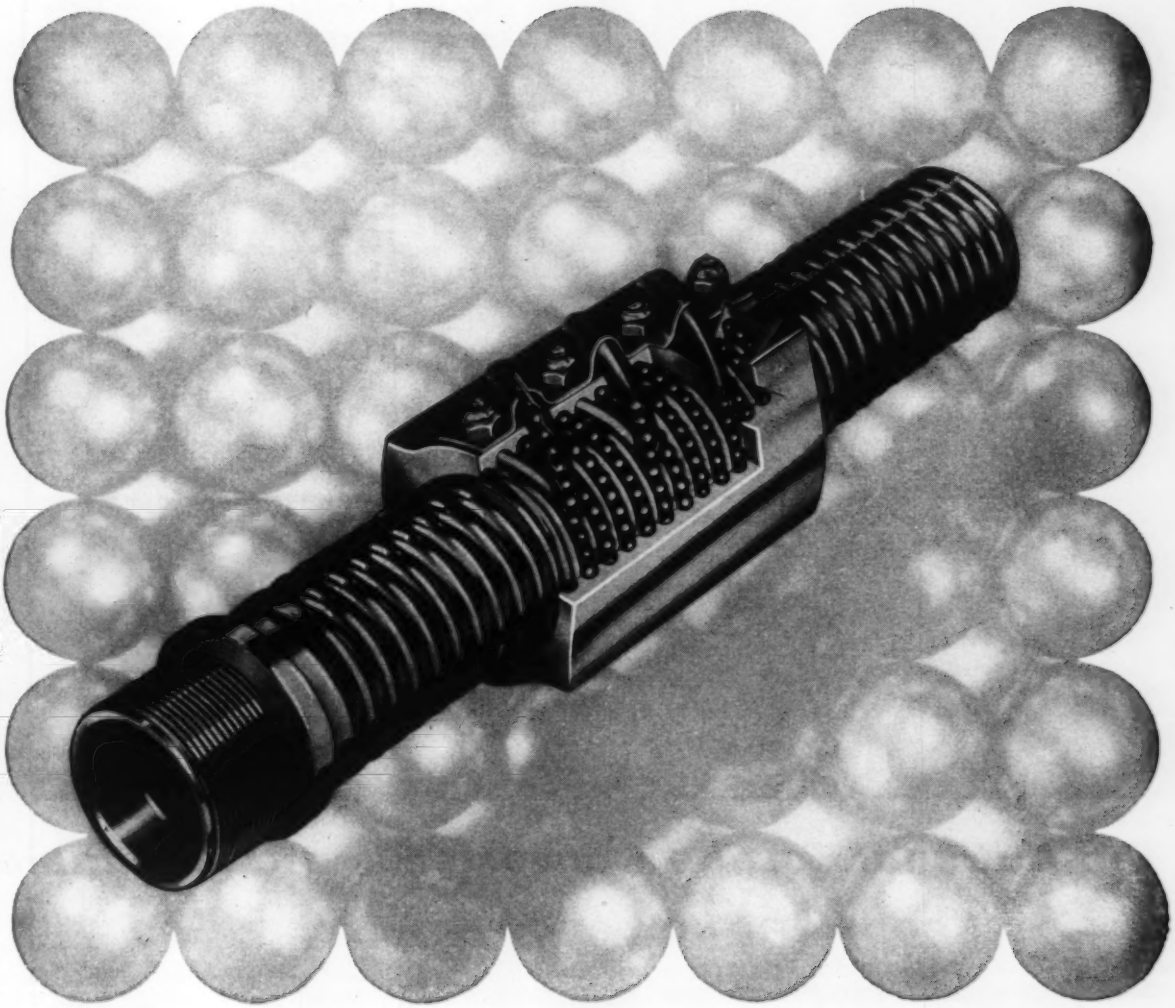

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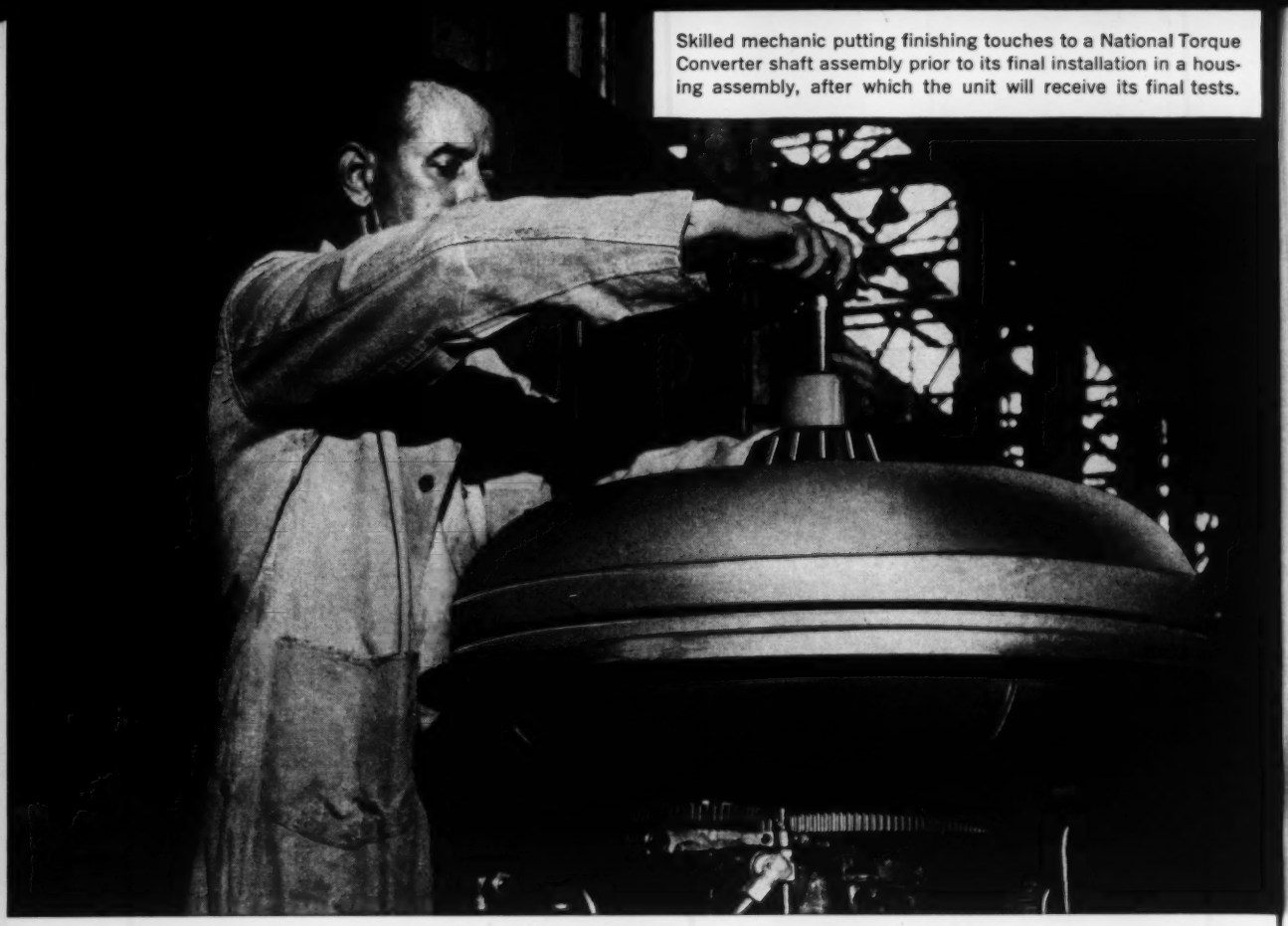

Skilled mechanic putting finishing touches to a National Torque Converter shaft assembly prior to its final installation in a housing assembly, after which the unit will receive its final tests.

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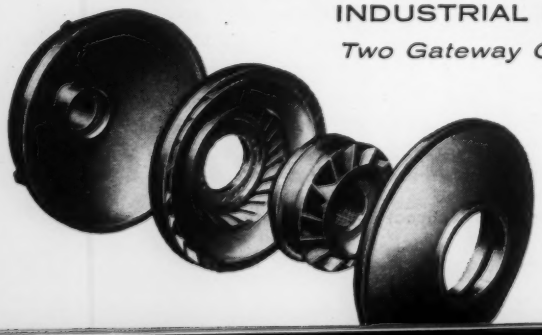

Pace-setters in the progress of industrial power transmission

Circle 558 on page 19

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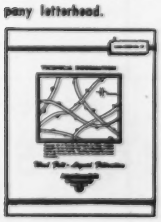

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Circle 559 on page 19

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These basic qualities account for the widespread use of ZINC Die Castings in many fields—uses which result in production short cuts to more durable and handsome products. For possible answers to *your* manufacturing design problems, send for our brochure and contact any commercial die casting company.

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Circle 560 on page 19

MACHINE DESIGN
NOVEMBER 1, 1956

A Shortage of Quality?

WE ARE frequently urged to explode the "myth" that there is a shortage of engineers. Yet industry obviously is crying for engineers. If this isn't a symptom of shortage, what is it?

It could be the result not so much of a numerical shortage as of an urgent need to build up a *competent* engineering work force. Anticipating ever fiercer competition—between companies and between nations—those responsible for administering engineering programs hope that, out of many hired, enough will prove to be superior engineers who can help maintain a competitive edge.

It all comes back to quality. Our competitors in the Soviet Union are meeting the problem by concentrating much of their educational efforts, from grade school up, on the sciences. Thereby they can reasonably expect to uncover virtually all the scientifically gifted and engineering-minded youngsters in the country. Through rigorous screening over the years, they can end up with a high average level of technical competence among graduates.

How are we doing by comparison? Recently published figures are shocking, to say the least. By the time he finishes *high school,* every Soviet student has taken 5 years of physics, 5 of biology, 4 of chemistry, 10 of mathematics and 1 year of astronomy. Fewer than 10 per cent of U. S. high-school graduates have taken as much as one year of physics and chemistry—even fewer have had any advanced mathematics.

The picture has at least two serious implications. On the one hand, among the 90 per cent of U. S. high-school graduates who never had the opportunity to study science, many may possess hidden scientific or engineering talents that perhaps will never be brought out. On the other hand, our colleges and universities must start practically from scratch in teaching mathematics and science; the Soviet colleges can pick up these subjects at a higher level and carry their students through much more advanced work.

The solution is out of the direct control of industry or of engineers as such. It is a public matter. But we can, as citizens and through our professional organizations, lend our influence, encouragement, support and personal efforts to every move toward the strengthening of science and mathematics teaching in our grade schools and high schools.

The present rate of graduation from engineering colleges could conceivably prove adequate for industry's needs if the general level of competence were sufficiently high. Coupled with proper utilization of these high-grade engineers, such a situation would greatly strengthen our profession and restore normal balance of supply and demand.

Colin Carmichael

EDITOR

Evaluating Engineering

Profit goals dictate periodic tests of engineering vitality. When vitality is low, performance falls off and growth stops. Physical examinations are a must, but management concern is usually prompted by trouble—trouble that could have been avoided by a policy of routine audits.

Patterns for engineering audits are relatively simple:

1. **Examination of the company's own engineering operations.**
2. **Examination of the practices of others.**
3. **Development of new programs based on the findings.**

Here's a 12-point plan of attack.

EVALUATING operations can hit wide of the mark when undertaken without a well-organized plan of attack. Specific areas to be covered should be established in advance. Operations analysis represents no small undertaking when worthwhile results are to be developed.

An organizational analysis may result merely in a panoramic picture of engineering activities, or it may represent a valuable and critical depth-penetration into engineering activities. The latter is the only worthwhile analysis. Management's objective is to increase the value of engineering's contribution to corporation profits.

Twelve criteria will be found useful in making an engineering audit. These criteria focus attention on critical and sensitive aspects of the technical organization. Each will be discussed in some detail beginning with an analysis of the role of engineering goals.

1. Clearly Stated Goals Should Be Established

The starting point in analyzing any engineering organization — your own or another's — is a study of the goals the organization is striving to achieve. Surprisingly enough, one of the most difficult jobs in organizational analysis is that of obtaining a statement of objectives. Too often there doesn't appear to be any general agreement on objectives within the engineering organization.

If you don't know what you are trying to do, it's hard to do the job successfully. Engineering organizations are just like individuals in this respect. Effectiveness is impaired when clearly stated goals are not established.

Engineering goals are determined by overall corporation goals. This fact has often proved a serious stumbling block for the engineering administrator. If corporation goals have not been established, engineering goals can't be developed. Overall corporation goals must come first.

Goals should be specific to be effective. It isn't enough to say that profits are the goal or that stability is an aim. Goals should be spelled out in detail.

Clearly stated goals should answer such questions as the following: What are we trying to achieve? In what time period? By what means? Where should this take place? At what cost? Why?

A statement of engineering goals doesn't remove the responsibility for creative thinking on the part of the engineering staff in any way whatever. Suggestions for amplifying and modifying these goals should flow in a steady stream from the engineering organization to management for review and action.

Goals give direction to engineering activities. Much of the criticism of technical activities is traceable directly to the absence of clearly stated goals for engineering activities. Once established they provide a basis for planning by the engineering administrator as well as a basis for measuring performance. Only with such administrative tools can the engineering administrator fill his proper role within the corporation. Only by knowing what he must deliver can he set about the task of insuring adequate performance.

2. Engineering Functions Should Be Balanced Against Goals

Most commonly, organizations are thought of in terms of organization charts. By themselves organization charts don't tell very much. Accompanied by a statement of the goals to be achieved, the organization chart provides part of the raw working data for a critical evaluation of an engineering organization.

By Philip Marvin
American Management Association
New York

Three questions are pertinent in making this evaluation:

1. Are all of the functions essential to the achievement of the desired goals accounted for on the organization chart?
2. Are any unnecessary functions present?
3. Are the functions stated in terms that can be easily understood?

The achievement of engineering goals usually calls for specific types of activities, both of a technical and nontechnical nature. Individual goals can be broken down into functions essential to their achievement. These functions can be checked off against those appearing on the organization chart.

Often in this process some confusion arises in an attempt to take available manpower into consideration at the same time. This is a procedural error. Functional analysis should take place quite independently of manpower studies. Functions essential to the achievement of goals should be established with complete objectivity.

At a later point in the overall organizational analysis, it may be found that one man must perform two functions or more. By contrast a single function may require the services of a dozen or more men. These findings at the proper time will constitute a vital part of the overall analysis. Such findings injected at this point in the evaluation impair objectivity.

Organizations must be built around functions, not men. This does not subordinate the importance of the individual. Effectively placed manpower is the basis of economic activity. Misplaced manpower is costly for the corporation and frustrating for the individual. Development of organizational structure around activities essential to the achievement of objectives insures that positions will be created wherein men may work with the greatest opportunity for efforts rewarding to themselves and to the corporation, both profitwise and satisfactionwise.

3. Engineering Standards Should Be Mutually Agreed Upon by Top Management And The Engineering Group

Basically the question is, "How good a product is to be designed?" In organizational analysis the engineering standards referred to are quality standards that will be reflected in the corporation's products. Top management and the engineering group must be in agreement.

At the outset one point may be bothersome. Why do engineering standards enter into considerations revolving around organizational analysis? The quality of the work to be performed determines the character of the engineering organization that must do the job. A high-quality product demands top-level engineering ability. Lesser performance demands result from lower-quality product requirements.

A corporation may manufacture a product that will sell over the counter in cut-rate stores, or the same type of product that will be sold to customers who put performance ahead of all other considerations. One product must be designed for price, the other for performance. One engineering group must sacrifice performance for cost advantages, the other must sacrifice costs for performance advantages.

Top management and engineering administrators do not always reach mutual agreement readily with respect to standards of engineering activities. One group usually wants engineering operations on a higher professional plane than the other. Agreement results from fact-gathering, analysis and decision. Once the decision is made it should be accepted and adhered to in all engineering operations until new facts can be produced to form an acceptable basis for altering the original decision.

A lack of mutual agreement on engineering standards by top management and the engineering group may be an underlying source of organizational problems. As such, it may be extremely difficult to detect.

Sound practice calls for probing into this possibility at the outset of an organizational analysis. Hidden ramifications are brought into the open and cannot cloud evaluation of other organizational factors.

4. Strong Leadership Should Be Available

Strong leadership is a catalysing force in any group activity. Effective leadership can double and triple the output. Leadership creates the team spirit. Strong leadership consists of more than merely giving instructions to a group. It is relatively easy to find people who can tell others what to do. Individuals who can assume full responsibility for leadership are rare.

The true leader, first of all, has the ability to stimulate in others a real desire to exercise the highest possible level of effort. Today we hear

so much about incentives that we sometimes forget that incentives are a poor and costly substitute for dynamic leadership. A good leader is a man who can instill in others a real desire to perform at top-level output.

A good leader, secondly, knows how to present assignments in such a way that a man understands why his individual role on the particular assignment is important and why he must concentrate his efforts on that particular assignment. Behind every good engineer lies a reason why he wants to do a good job. One of the causes of poor performance lies in failure to link the engineer's basic desires and interests to the job at hand. A good leader spots these weaknesses where they exist and concentrates on developing a harmonious relationship.

Finally, a good leader has a job of instructing and guiding engineering associates in the performance of specific tasks. Good leadership not only shows the junior engineer how to execute today's assignment, but how to do it in a way that prepares for tomorrow's assignments and responsibilities.

These are leadership roles. Accepted and carried out, they multiply the effectiveness of the organization's manpower. Analysis should reveal the leaders, where they are, and the spots where leadership is lacking. It is not enough to be capable of doing a job; ability must be coupled to leadership for organizational or personal growth.

5. Policies Should Govern Operations

Engineering management can profit greatly from a review of its policies. Policies are basic management tools. They improve performance and lighten management's job. Engineering managers who find themselves faced with the necessity of making repeated decisions on matters that are similar in nature can save themselves time by formulating policies covering subject areas in question.

For example, in many engineering organizations, technical society memberships must be approved by the engineering administrator. A policy, and its reasons, outlining the basis for approval of technical memberships to be paid by the company eliminate repeated decisions and clarify a matter of importance to all engineers in the department.

A parallel case is represented by trips to technical meetings. Quite commonly engineers are completely in the dark as to whether or not such attendance is favored. Individually they must approach their supervisor, who in turn may be required to discuss the matter one and sometimes as many as two layers up in the engineering group. All of this could be expedited by a clearly stated policy.

Two possible reasons may explain absence of policies. First, engineering management may not be educated up to the level of policy development. Second, engineering management may not be sufficiently in control of the situation to permit policy development. Either fact is quite revealing.

Engineering managers cannot operate effectively without policies to cover matters that are of a recurrent nature. Time is wasted in making separate decisions and decisions themselves are seldom consistent. Lack of consistency gives rise to further problems for the engineering manager.

If it were possible to select a single criterion to serve as a measure of the quality of an engineering organization, it would probably be based somehow on a measure of the adequacy of the policies established to govern the group's activities.

6. Engineering Tools Should Be Available

The increasing technological complexities of our present way of living are reflected by the elaborate nature of the tools required by today's engineers. Today's computer that may rent for as much as $50,000 a month is a far cry from the days when a $5 slide rule was the backbone of advanced engineering calculations.

Unless engineering management is prepared to make these new tools available and is prepared to replace them with even more advanced tools as rapidly as they become available; engineering output will suffer both in quality and quantity.

An evaluation of the engineering organization as part of a process of continually strengthening its role must give careful consideration to an analysis of available tools. Such an analysis must be based first on a study of both the current state of technology and the direction indicated by those who are working at its horizon. The analysis should serve to reveal the tools needed to equip a technical group to do work guaranteeing that the corporation will not be left behind its competitors. Available equipment can be compared with the results of this study.

New tools represent a great deal more than timesaving devices in the usual sense of the word. An electronic computer of the advanced type can carry out calculations in one hour that an engineer with a mechanical desk calculator would require 15 years to complete. By the time he completed such a fantastic task, the results would have been rendered meaningless by the inexorable march of technology.

New tools represent new technologies also. Developments such as the nuclear reactor have become basic tools. For example, any engineering laboratory to execute an assignment in the area of power generation, propulsion equipment, or other major segment of the broad spectrum of engineering activity, must have such a tool available.

Knowledge of these requirements enters into the organizational analysis because the tools themselves represent determining factors in final decisions with respect to organizational development. Too little, too late can be very costly to the corporation's industry position and profit picture.

7. Resources Must Be Organized for Performance

Reporting relationships in the engineering department reveal some of the reasons for its effectiveness or ineffectiveness, as the case may be.

A few weeks ago the author sat in the office of an engineering manager. During the visit, our discussions were interrupted by a succession of telephone calls and visits by staff members who dropped into this man's office to get decisions on matters of apparent importance. Apologizing for these interruptions, this engineering manager said that his group depended upon him for every decision. Perhaps one should have been impressed by his busyness, but a more realistic reaction was one of dismay. This man was too busy to think. Not only was his own time tied up needlessly but his staff members were wasting valuable time in contacting him for every decision.

The reason for this steady stream of interruptions became apparent when this question was posed: "Have you delegated authority to these men so that they can act on these matters on their own initiative?" The answer was negative. This man apparently didn't know how to find out which of his engineers were capable of assuming added responsibility. He didn't know how to surround himself with capable engineers.

An administrator can't work effectively if he has more than five men reporting to him. Moreover, this statement assumes that these five men are highly competent men who can assume full responsibility for their respective areas of operation.

Engineering functions should be grouped together in a manner such that no more than five men report to the top engineering executive. This policy must extend down into the engineering organization.

Adequate authority must be delegated to those in subordinate positions. Authority must be commensurate with responsibilities if subordinates are to act effectively. Clearly established channels of accountability will serve as effective checks on performance.

Structural aspects of these reporting relationships among the various engineering functions reveal why competent engineering managers are never too busy to think.

8. Functions Must Be Adequately Manned

The current scarcity of engineers doesn't create the most ideal atmosphere for a discussion of manpower analysis. It's too easy to shrug the problem off with a "let's leave well enough alone" attitude. Development of the engineering organization grinds to a halt as a result of thinking along these lines. Regardless of difficulties encountered in the manpower market, the right man for the right job is essential to optimum performance. Any relaxation of efforts in this direction is at the expense of output.

It has been said that organizations are built around men. More realistically, organizations are built around functions, but we don't get any output until we staff these functions with the right kind of manpower. First we need to define the jobs we wish to accomplish, then we should determine the functions that are essential to these jobs, and finally, we must staff these functions.

Manpower programs that are not based on this logical step-by-step procedure are bound to develop serious organizational problems. Performance of the best available men becomes totally ineffective when positions are not clearly tied to overall goals. Before troubleshooting the man, check his function in relationship to other functions and departmental goals.

Manpower selection should consider two aspects of the applicant: his capacity to do the immediate job required of him, and his capacity to grow in capability. Growth capacity may be more important in the long run.

Few engineering assignments have static characteristics. What we sometimes consider to be a static job generally is an assignment that calls upon an engineer to take hold of a project and to grow with that project in a rapidly changing technological environment. It can be said with considerable assurance that any assignment that is static in nature is not an engineering assignment.

Ability coupled to growth capacity summarizes the qualities that are sought after in the engineering organization. Should it be necessary to weigh their relative importance, growth capacity would represent the better gamble for today's engineering organization.

9. Corporation Interests Must Come Before Personal Interests

How often do you find men placing personal interests before company interests? This is a matter of real management concern because it represents a loss in time and money. Engineers who don't place company business first can't perform at top level. You can't put forth your best efforts when you aren't 100 per cent behind your job.

One of the reasons for poor performance in the engineering organization is directly attributable to the fact that some engineers regard their own personal interests as something quite foreign to those of the corporation. Engineers aren't entirely to blame; management has been guilty in a number of instances of adopting a standoffish attitude in dealing with its engineers — an attitude which is quite understandably reflected by engineers in turn.

In making an organizational evaluation, you

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need to know the degree to which engineers place their own personal interests first, ahead of the corporation's interests. But this isn't enough. You need, also, to know the reasons for this attitude of passive co-operation.

Some pertinent questions to ask in this connection in conducting an organizational analysis are: Have the engineers been taken into management's confidence? Have they been acquainted with corporation interests? Do they know the whys and wherefores? Do they know the importance of their individual roles as engineers? Have policies been such that engineering efforts have been recognized?

A great many engineering hours are wasted because engineers arn't wholly behind their jobs. Corporation time is spent on projects of a very personal nature. These men are working part time for the corporation and part time for themselves. Such men are actually wasting their own time and don't realize it. They aren't establishing any record for themselves in the organization because of their indifference.

Most of these men can be guided into paths of greater productivity by aligning their interests with those of their employer. This is a management responsibility. Acceptance of this responsibility is a measure of management's effectiveness. Alignment of individual interests with those of the corporation is a measure of organizational strength.

10. Planning Should Precede Action

Planned action is effective action. Few will disagree. Yet planning activities that adequately delve into their assignment to effective depths are rare.

A good plan represents more than a way of doing something. A plan is a definitely determined basis for action. It represents a practical approach to the job at hand. It anticipates a more than average number of obstacles in its path. Allowance is made for these in the well-planned program.

Engineers are supposed to be extremely practical; yet this attitude isn't always carried over into the management phase of engineering operations. Planning isn't always rigorous. It doesn't always anticipate trouble.

Planning activities should undergo continuing scrutiny in the course of an organizational analysis.

Particular attention should be directed to three aspects of plans themselves. Do plans represent a sound course of action? Do plans represent a complete program? Do plans incorporate alternate courses of action to be followed in the event that initially planned courses are blocked?

This last phase seems to give engineers the greatest difficulty. In substance it amounts to advanced trouble-shooting. You visualize the plan set in motion. Next you apply your imagination to the process of anticipating everything that can possibly go wrong with the plan. Then you plan around each of these dificulties in advance of their possible occurrence.

The tactics and strategy are quite similar to those employed when a Very Important Person visits town. He may be scheduled to travel by car down the main street, but you keep the side streets open and you keep a street parallel to the main street clear too. Should trouble occur, bypass arteries are in a stand-by condition.

Engineering planning activities that are functioning properly guide programs in pre-established channels to completed goals in a minimum of time and at a minimum cost.

11. Operating Controls Should Be Functioning

To conserve its own time, engineering management should establish a system of controls that provide check points at all phases of engineering operations. One of the secrets of good management is the efficient use of controls as timesavers.

Management men need to know the current status of operations at all times if they are to plan and regulate activities. In the course of an organizational analysis, these controls should be spotted and evaluated. Where are they located? What do they tell management? When do they tell management? Whom, specifically, do they tell? This last question can be extremely important. Instances have been observed of control systems that functioned perfectly in every respect but one—the data were not directed to management, no effective action could be taken!

The time to establish controls arises when programs are developed. At this point, while programs are foremost in mind, management is in a position to stake-out control points where they are needed.

One of the most obvious factors to be controlled is that of timing. Engineering programs should be broken down into divisions of activity whose end product is readily distinguishable. Estimated time-of-arrival figures should be established for these divisional points.

Both times and divisional points are interrelated elements of time tables. Times don't mean anything unless a clear line of delineation in activity is apparent. For example, check points have been established by engineering managers calling for completion of one-half of a literature search by a certain time. Such a check point is impractical. There is no way of knowing when you are half way through a literature search anymore than there is of knowing when you are halfway through thinking up a new idea. You can estimate the time required for each of these, perhaps, but you can tell how long you actually required to do the job only after you have completed the activity.

Detailed jobs such as, for example, the preparation of tracings can be checked at midpoints because the nature of the task is such that it can be

broken down into readily recognizable segments.

Check points should encompass quantitative and qualitative factors as well as timetables. Management should learn the answers to such questions as "How much?" and "How good?" at frequent intervals as programs unfold. It should be emphasized that these questions should be injected only at points at which it is possible to get informative data.

Controls are a management tool. They multiply management's effectiveness. Much can be learned about an engineering manager's method of operation from an analysis of the controls he employs.

12. Operations Should Be Researched

In the course of analyzing an engineering organization, an examination should be made of operations themselves. It is easy to commit the error of looking at organization charts, studying goals and other factors, and then jumping to the conclusion that these tell the whole story. Sometimes they do, more often they don't.

The only way to learn about an organization is to study its day-to-day workings. Comparison of daily working relationships with the more theoretical aspect of plans, etc., reveals the full impact of these on actual operations.

Our primary interest lies in learning about the management process that produces the results gained by organizing efforts. Operations themselves tell the real story. Often actual operations are found to be at considerable variance with the manner in which engineering managers visualize their operations. Such a situation creates speculation as to whether current operations are more productive, proceeding as they are, than they would be proceeding in accordance with the planned program.

Operations should be researched to establish actual concurrent and sequential working relationships for comparison with planned programs. In addition, operations should be studied as a basis for establishing new operational concepts that can be developed and implemented in the interests of improved engineering activities.

Enginering operations should also be studied in view of overall corporation activities and products. Changes in procedures and systems outside of the engineering organization that could have a marked effect in raising levels of performance within the engineering organization should not be overlooked where a net benefit would accrue to the corporation.

The need for operations research arises because new problems arise out of everyday working relationships. Problems are created when programs are put into motion. Unrecognized, these may represent either lost opportunities or hidden costs. By means of operations research, operating relationships can be capitalized upon or modified in the interests of overall engineering effectiveness.

Analyze and Revitalize

The end product of an evaluation should form the basis for specific management action taken to strengthen engineering activities. Evaluation should be both qualitative and quantitative in nature. Results should guide management in revitalizing the engineering group.

The 12 criteria presented are fundamental to sound engineering management. Effective use of these criteria will depend in part on management's skill in their application. Increased profits can be the reward. Management must couple analytical skill with courageous action to strengthen the engineering organization for the productive output of engineering's hardware—new and lower cost products, processes and services—as the basis of increased corporation earnings in the years ahead.

Tips and Techniques

Keeping Drawings Clean

A coating of paste (automobile type) wax applied to triangles, templates and straightedges will prevent their picking up graphite dust and smudging drawings. Additionally, the wax coating prevents or retards wearing away of printing or graduations on these implements. — ERNEST JONES, *Bronx, N. Y.*

Mental Calculation

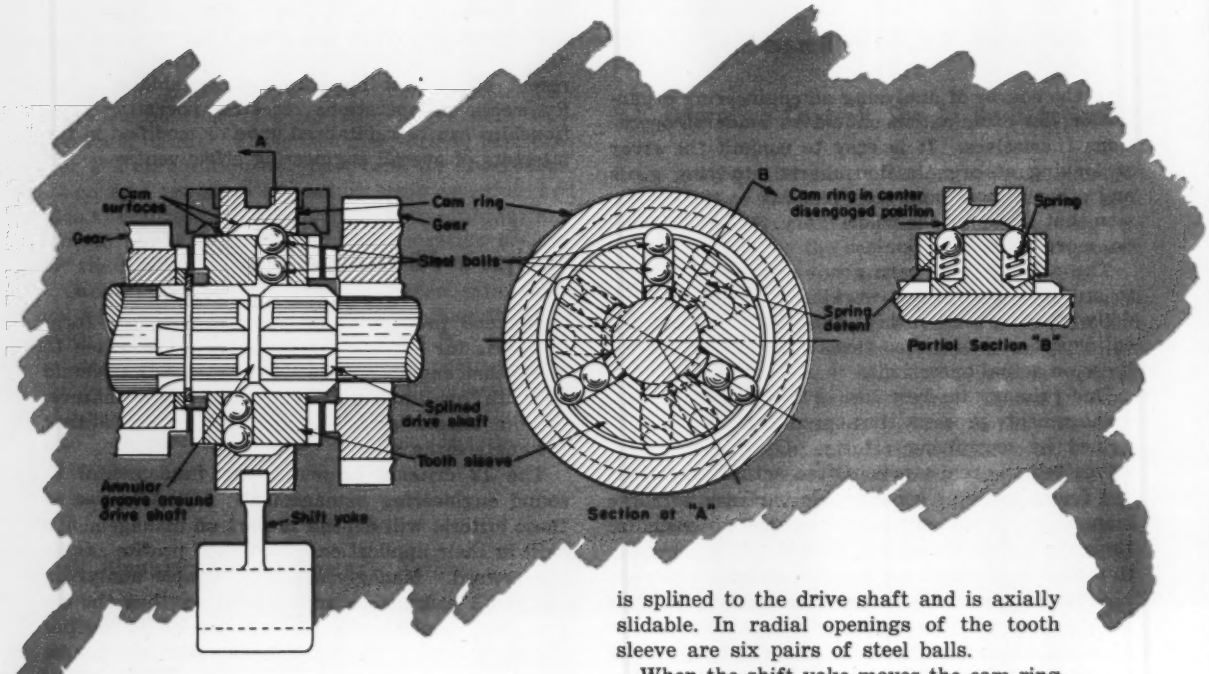
Use of certain basic mathematical relationships can simplify many calculations so they may be done mentally rather than with slide rule or pencil and paper. One of the simplest of these is $(a + b)(a - b) = a^2 - b^2$. Applying this to a multiplication such as 33×27, for example, leads to $(30 + 3)(30 - 3) = 30^2 - 3^2 = 900 - 9 = 891$.

The relationship $(a + b)^2 = a^2 + 2ab + b^2$ can also be similarly employed for squaring numbers. Using this relationship $36^2 = 30^2 + 2(30)(6) + 6^2 = 900 + 360 + 36 = 1296$.

Another of these useful relationships is $a(a + b) = a^2 + ab$. As an example, $25 \times 28 = 25(25 + 3) = 625 + 75 = 700$.—R. H. KAROL, *Karol-Warner, Highland Park, N. J.*

Do you have a helpful tip or technique for our other readers? You'll receive ten dollars or more for each published contribution. Send a short description plus drawings, tables or photos to: Tips and Techniques Editor, MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

scanning the field for Ideas



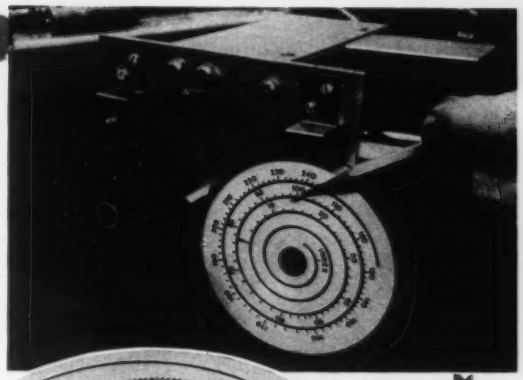
SELF-LOCKING CLUTCH design can be easily disengaged while transmitting full-torque loads. Developed at the A. Y. Dodge Co., the design is employed in a tooth clutch unit which positively locks itself into engagement until a shift is required.

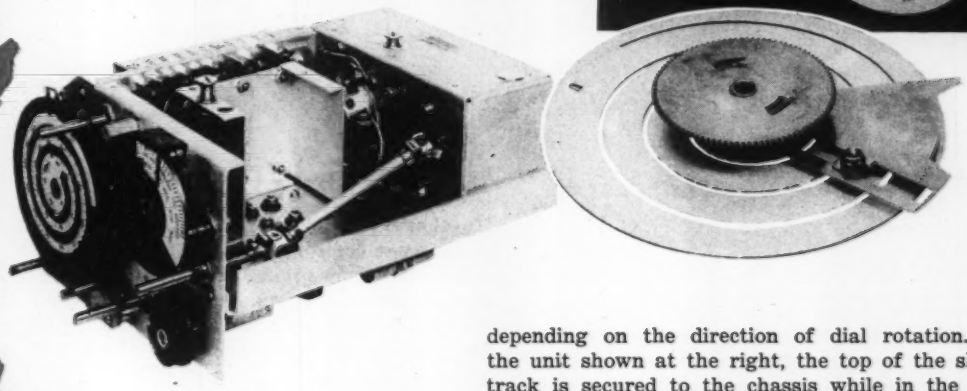
Shifting and locking are accomplished by means of a novel construction which employs a shift yoke, a cam ring, a tooth sleeve, an annular groove in the splined portion of the drive shaft, several steel balls, and three pairs of spring detents. The shift yoke simply engages with the cam ring. In construction the cam ring is an annular collar designed with a wide groove on its inner surface terminated with cam surfaces at each side that make acute angles with the shaft axis. The tooth sleeve, which has clutch teeth at each end, is splined to the drive shaft and is axially slidable. In radial openings of the tooth sleeve are six pairs of steel balls.

When the shift yoke moves the cam ring axially in a given direction, the cam ring engages with the outer ball of three pairs of balls and the tooth sleeve is forced to slide axially in the same direction. When the three pairs of balls, which are doing the shifting, are moved over the annular groove around the drive shaft, the balls move radially inward and the cam ring can ride up on top of the balls. This condition positively locks the tooth sleeve into position.

The spring detents automatically hold the cam ring in either of the two engaged positions or the center disengaged position. When the cam ring is shifted slightly by the yoke in one axial direction or the other, the appropriate set of spring detents engages cam surfaces in the cam ring to automatically move it farther in that direction.

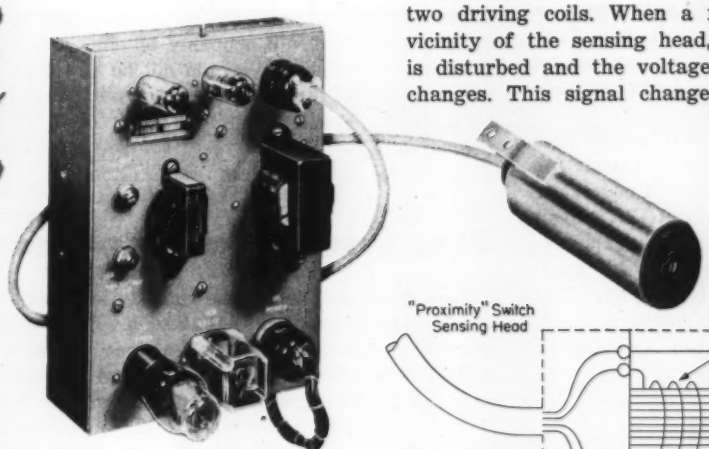
SPIRAL DIAL DESIGN increases accuracy of manual settings of tuner in Bell Telephone military radio-transmitter unit. The dials, which are made of sheet metal, are stamped out with a spiral-shaped slot and are mounted on a central hub member. A spring-load gear that drives the dial is also mounted on the same hub member. The pointer protrudes through the spiral slot from the back and is mounted on a slider. The slider rides in a track and is moved up or down by the spiral slot,

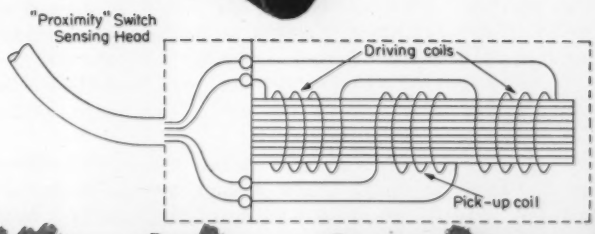


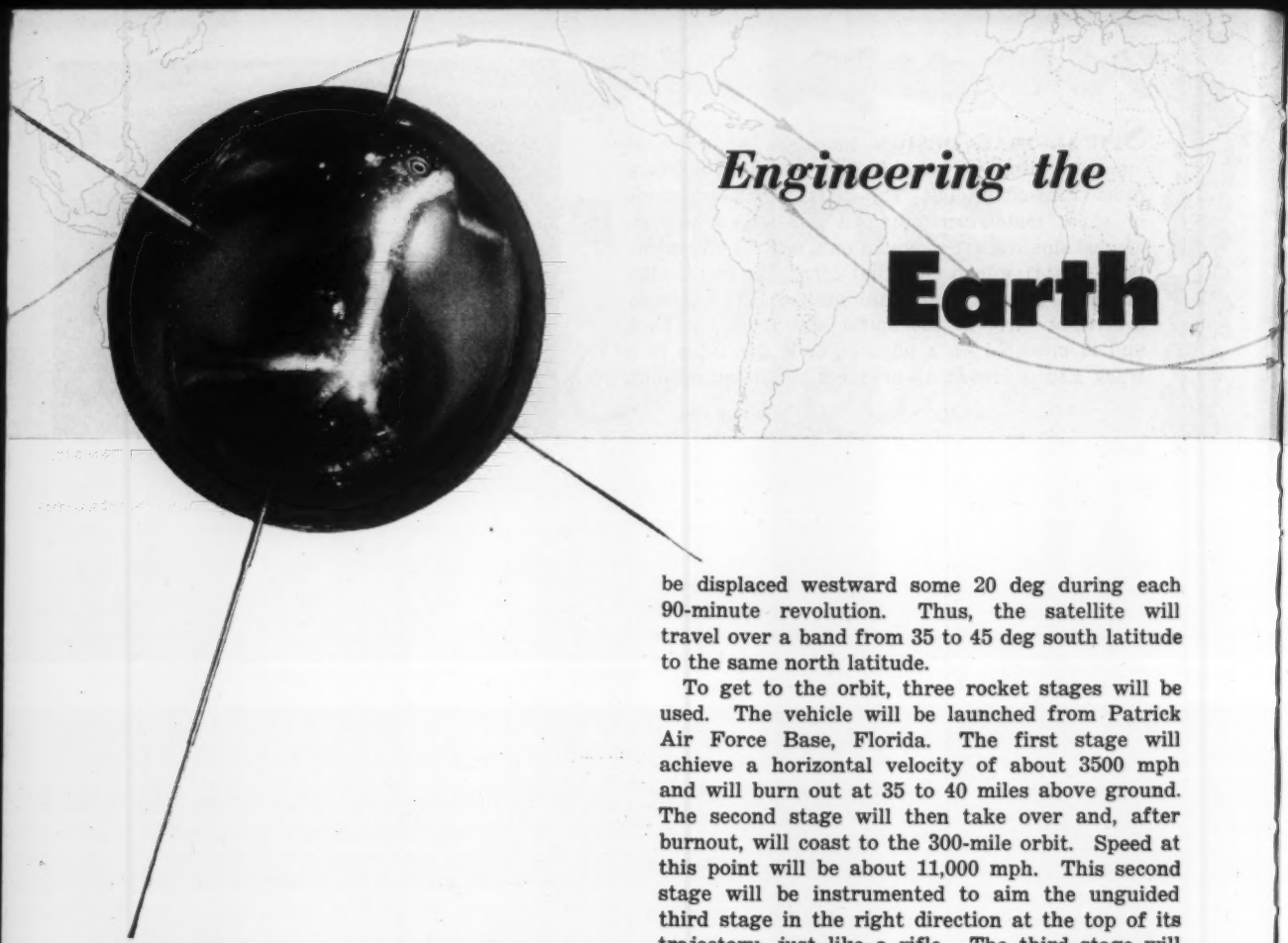


depending on the direction of dial rotation. In the unit shown at the right, the top of the slider track is secured to the chassis while in the unit at the left the track assembly is mounted on a hub at the bottom and held in a grooved pulley. In the latter design, the track, which floats on the hub, can rotate a few degrees to permit changes in relative angular location of pointer. The dials are made by the John Gombos Co. Inc.

PROXIMITY CONTROL OF LIMIT SWITCH OPERATION permits conversion of mechanical position or motion into an electrical signal without physical contact between the part and the switch. In a limit switch design developed by Square D Co., the sensing unit consists of a differential transformer made up of three coils wound on a single core. The two driving coils, which are energized from a constant-voltage supply, set up a standing magnetic field. The pickup coil feeds back a voltage signal, the shape of which depends on the net flux of the ac magnetic fields generated by the two driving coils. When a ferrous part moves into the vicinity of the sensing head, the standing magnetic field is disturbed and the voltage signal from the pickup coil changes. This signal change can be used to operate an electrical or electronic control circuit, eliminating the need for mechanical contact with the switch.







Engineering the Earth

DURING the next two years, a half-dozen or so man-made "moons" will speed by overhead at over 18,000 mph. Lifted 300 miles out into space, each tiny satellite will circle the earth for 15 days to a year before losing speed and burning up in the long plunge through the earth's atmosphere.

It takes 22,000 lb of rocketry to place one 21½-lb satellite in its orbit. But the information gained is expected to be fully worth the engineering and manufacturing effort expended. For the first time, scientists will be able to make observations free of the earth's blanket of air. And the satellite will be man's first step into space.

Project Vanguard—the earth satellite project—is part of the United States scientific program for the International Geophysical Year. Undertaken by the U. S. National Committee for IGY, Project Vanguard is using the resources of the Department of Defense, which is responsible for engineering and logistics phases of the project. This joint Navy-Air Force-Army participation is under the management of the Naval Research Laboratory.

The Orbit

Orbit of the satellite is nominally a circle, 300 miles from the earth's surface. Plane of the orbit will be inclined 35 to 45 deg to the plane of the earth's equator. The satellite will go around the earth once every 90 minutes. Since the earth rotates "underneath" the orbit, the satellite orbit will be displaced westward some 20 deg during each 90-minute revolution. Thus, the satellite will travel over a band from 35 to 45 deg south latitude to the same north latitude.

To get to the orbit, three rocket stages will be used. The vehicle will be launched from Patrick Air Force Base, Florida. The first stage will achieve a horizontal velocity of about 3500 mph and will burn out at 35 to 40 miles above ground. The second stage will then take over and, after burnout, will coast to the 300-mile orbit. Speed at this point will be about 11,000 mph. This second stage will be instrumented to aim the unguided third stage in the right direction at the top of its trajectory, just like a rifle. The third stage will then provide the power to raise the satelite's velocity to 18,000 mph. At third-stage burnout—some 1500 miles down track from the launching site—the satellite will be "kicked" off the third-stage rocket. Both the satellite and third-stage rocket will then orbit, although in slightly different paths.

Actually, the intended orbital distance of 300 miles will probably not be attained. Because of slight accumulated errors of height, angle and velocity, the orbit will probably be elliptical. Nearest approach, however, should not be less than 200 miles, and the furthest extension not more than 1500 miles. For a 300-mile circular orbit, life of the satellite would be 1 year; for 200 miles about 15 days; for 100 miles less than an hour.

The Launching Rockets

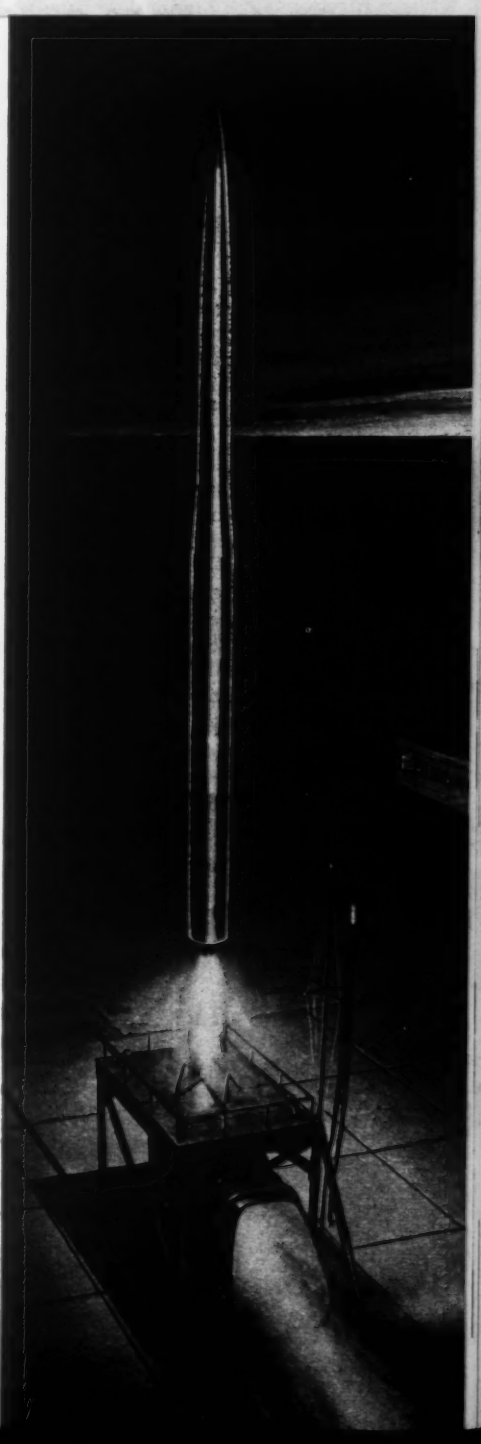
Launching vehicle for the satellite will be a 72-ft three-stage rocket weighing 11 tons. Present plans are for the vehicle to reach a speed of at least 18,000 mph. If the three-stage rocket matches design calculations, it may reach 19,000 mph or better.

The Three Stages: The first stage is a redesigned Viking rocket, powered by a new 27,000 lb thrust rocket motor. The motor—over twice as powerful as today's best jet engines—is being built by GE for the Martin Co. The Viking will serve primarily as the muscles to lift the other stages.

By Robert L. Stedfeld
Associate Managing Editor, Machine Design

Satellite

A report on the engineering status of man's first step into space



The second stage, built by Aerojet-General Corp. and also a liquid-propelled rocket, contains the complete guidance system for the entire vehicle: a magnetic-amplifier autopilot for course control and an inertial gyro reference system that corrects the vehicle's orientation. This stage also contains the mechanism for spinning the third-stage rocket.

Spin of 100 to 300 rpm on the third-stage rocket is necessary to stabilize it "on course," since this stage will not be guided. Two versions of the solid-propellant rocket will be built: a conventional metal rocket and one of spun glass (and presumably plastic) material. The third-stage rocket, being developed by Grand Central Rocket Co. and the Allegany Ballistics Laboratory of Hercules Powder Co., will also nudge the satellite into its orbit when top speed is reached with either an explosive charge or a spring.

Propulsion Systems: Liquid-propellant rocket motors for both the first and second stages will be gimbal-mounted—free to turn up to 5 degrees in any direction about the rocket's longitudinal axis. The guidance system contained in the second stage positions the motors to keep the vehicle on its programmed course. This control method also stabilizes the airframe in both pitch and yaw. Thrust of the motor "balances" the rocket, much like balancing a baseball bat on the end of a finger. Swiveling exhaust ports or "jet reactors" located outside the rocket skin prevent roll.

Gasoline and ethyl alcohol, with liquid oxygen as an oxidizer, will be the propellants for the first-stage rocket motor. This motor will operate for 140 sec. The thrust chamber is a double-walled regeneratively cooled unit in which the fuel and oxidizer are burned. Fuel and oxygen are injected by turbine-driven pumps powered by the decomposition products of hydrogen peroxide. The turbine also drives a hydraulic pump for the controls. Helium pressurizes the propellant tanks from which fuel and oxidizer flow to the pumps.

Second-stage rocket motor will use fuming nitric acid and unsymmetrical dimethyl hydrazene as oxidizer and fuel. Again helium pressurizes the fuel tanks. Details of the third-stage propellant

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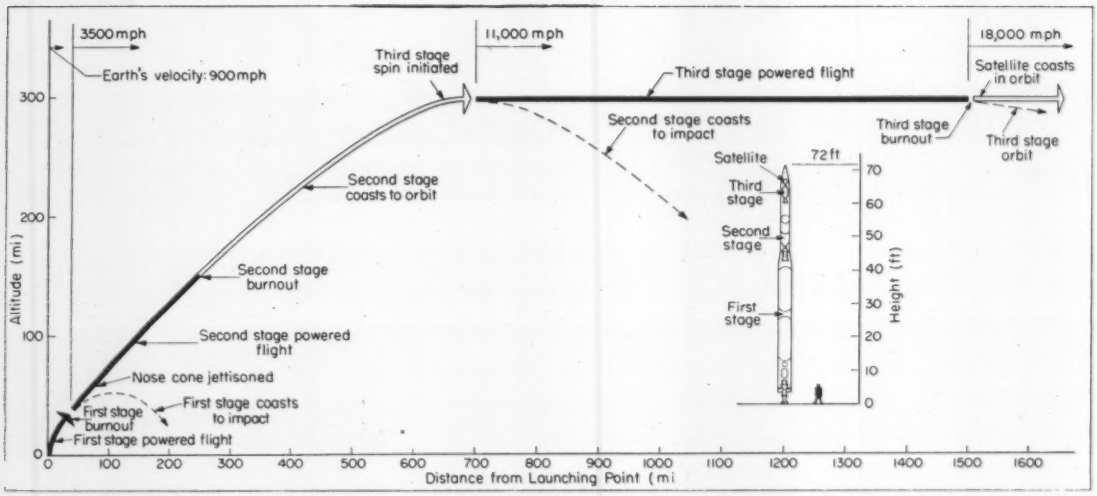


Trajectory of three-stage Project Vanguard rocket, and orbit of the satellite. Inset shows size of Vanguard vehicle compared to a man.

and motor are not yet available.

Airframe Structures: Only 14 per cent of the weight of the entire Vanguard rocket is airframe structure; the rest is fuel, propulsion units and control system. Monocoque construction will be used to achieve the light weight needed to maintain a high mass ratio—the ratio of fuel weight to gross take-off weight of the vehicle.

First stage is slightly longer than a Viking Rocket—about 45 ft—but will have a simpler structure. Except for the engine and accessories compartment at the base, the first stage will consist of two stressed-skin fuel tanks for the liquid fuel and oxidizer.

Two aluminum walls form the tank sides, and also the outer skin of the first-stage rocket. Each is supported by two channel frames and dome-shaped headers. Joints between the skins and headers will be reinforced by an aluminum extrusion. Metal parts are spot welded, then fusion welded to provide a leakproof joint. Tank headers are welded to the extruded frame along a scalloped edge, which provides a longer weld to strengthen the joint.

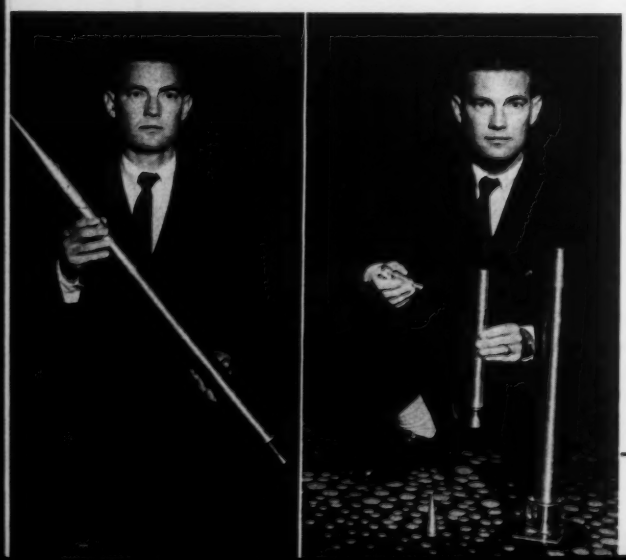
Aft of the fuel tanks in the first section, aluminum frames and stringers will be used, to which magnesium skins will be riveted. The motor and its gimbal mounting are attached to the structures at four mounting points. Forward of the main tanks is a transition section, a riveted assembly of aluminum frames and magnesium skins.

The second stage—32 in. in diameter and about 31 ft long—contains the third stage within its forward section, and also the controlling units and mechanisms for the entire rocket assembly. This section, made of aluminum and magnesium, also carries the fittings and mechanisms to jettison the nose cone which protects the satellite and reduces drag during the first 60 miles of the vehicle's travel. Fuel tanks will be built of 17-7PH stainless steel because of the corrosive propellants.

The nose cone is made in two parts for easy separation. Just behind it the satellite and third-stage rocket are mounted on a rotating turntable. Spinning motion of 100 to 300 rpm will be imparted by small solid-propellant rockets.

Control and Guidance System: A teamed Minneapolis-Honeywell three-axis inertial guidance system and Vickers Electric magnetic-amplifier autopilot will control the Vanguard vehicle's course.

The three-axis reference system consists basically of three gyros which "memorize" the vehicle's three heading references—roll, pitch and yaw. The pitch and yaw gyros control direction of thrust of



Model of launching vehicle, held by J. Paul Walsh, deputy director of Project Vanguard. Second stage, held by Mr. Walsh, fits on top of first stage. Third stage and satellite fit inside the second stage, under a nose cone which is jettisoned during flight.

the first and second-stage rocket engines through the autopilot and servo system actuators. The roll gyro controls firing of the jet reactors which correct for roll. To control the course, the pitch gyro axis will be rotated to a new heading.

Known as "hermetic integrating gyros" or HIG-6, the inertial reference system has gyro wheels about 1 in. in diameter and ¼-in. thick. They spin at 12,000 rpm, driven by a 400-cycle system, and are polished to accuracies of 0.00001-in. The complete assembly for each gyro consists of the wheel or rotor, a gimbal mounting for the wheel, a signal pickoff and torque generator, all enclosed in a cylindrical container weighing 4.6 lb, 5.9 in. long and 3.07 in. in diameter—about the size of a can of peas.

This can is hermetically sealed. The gimbal inside the can is "floated" on a syrupy fluid (Flurolube) at the middle and supported by miniature jewel bearings at each end. Signal pickoff and torque generator units are at the ends of the gyro case. Since the gimbal (which weighs almost 1 lb) is floated, the jeweled bearings serve only as guides, resulting in near frictionless operation.

Damping characteristics of the Flurolube result in a gimbal deflection rate proportional to the ratio of rotation of the gyro case. Accuracy-wise, the HIG is said to measure deflection rates as small as 0.00003-deg per sec.

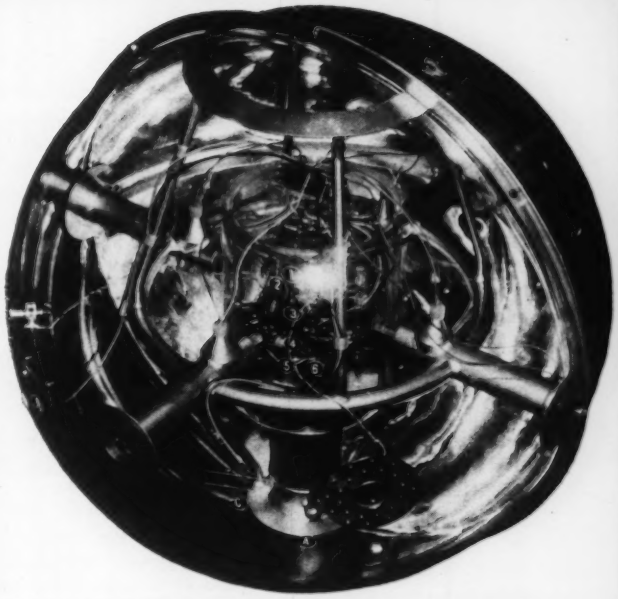
To control the trajectory of the vehicle, the heading of the pitch gyro must be changed. This change in pitch-gyro direction will be controlled by a programming device feeding into the gyro's torque generator. The torque generator, similar in principle to an electromagnet, will act on precisely controlled dc current signals to rotate the gyro gimbal to the new axis.

The Earth Satellite

The satellite itself will be a highly polished sphere 20 in. in diameter, weighing about 21½ lb. Of this weight, about half will probably go into the satellite shell, brackets and other structures in the shell, and the attachment to the third stage rocket. The rest—about 10 lb—will consist of (1) a radio tracking oscillator and transmitter, (2) telemetering equipment, (3) antennas and (4) instrumentation. Obviously, not much room is available for scientific experiments, so attention has been concentrated on designing out every last ounce.

Satellite Shell and Structure: Present plans call for use of a magnesium shell and internal supporting structure. The shell itself will weigh between 3 and 4 lb, and will be made in two hemispheres joined at the center. Between 10 and 15 shells will be built. Most will be used for testing: about 6 will actually be launched.

The first shell is now being made by Brooks & Perkins Inc. It will be spun from AZ31B magnesium alloy 0.064-in. thick. The halves will then be machined to a minimum thickness of about 0.020-in. tapering to 0.050-in. at the attachment point to the third-stage rocket. Other sections will also be left thicker for reinforcement and instrument mounting bracket.

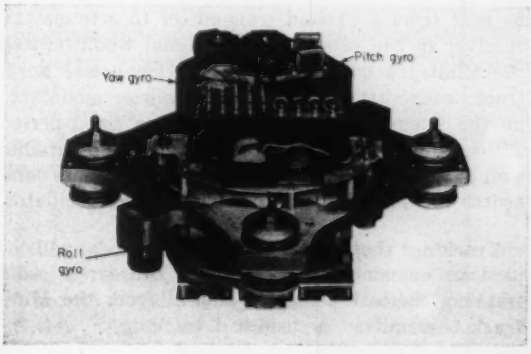


Official model of the earth satellite. In the central core of the satellite are the Minitrack radio transmitter, telemetering equipment, batteries, and memory units for retaining data until the satellite passed over a ground station. Mounted on the shell is the instrumentation; shown on this model are a cell operating on solar energy to record each orbit around earth, an ultraviolet detector, strip-mounted thermistors to detect temperature, and an external-mounted erosion gage.

Outside of the shell will be contour machined and polished to a 4 microinch finish, to aid optical tracking when the satellite is aloft.

Minitrack Radio Tracking System: To track the satellite by radio, a lightweight single-stage, crystal-controlled transmitter powered by batteries will be used.

The Minitrack system developed by Naval Research Laboratory consists of a 10 to 20 milliwatt transmitter operating on a fixed frequency of 108

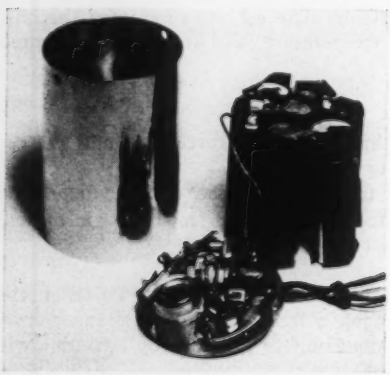


Three-axis gyro system which maintains rocket stability in flight. System is part of the Vanguard Vehicle's "brains," located in the forward end of the second-stage rocket.

megacycles. Two developments are under consideration, one using subminiature, low-filament-current vacuum tubes and the other using transistors. Both units are crystal controlled for frequency stability and are designed for a minimum operating life of 350 hr—slightly over 2 weeks. The transistorized unit would be lighter and smaller (2 lb for antenna, antenna phasing system, oscillator and batteries for 20 milliwatt output). But temperature may be a problem, and reliability might be better for the radio-tube system.

One 10-milliwatt transistorized system, for instance, uses specially designed Western Electric or Philco transistors. Battery pack consists of seven 1.2-v mercury cells, Mallory type RM-12. An aluminum container, gold plated for heat reflectivity, houses the unit. Total weight is 13 oz.

Battery types, too, are still unsettled. Because of the vacuum in which the satellite moves, all batteries will probably require pressurization. Of the common types, the zinc-silver-oxide cell, zinc-mercury cell, and indium-mercuric-oxide cell appear to be able to meet requirements for temperature, pressure, weight and size. Solar cells appear to hold some interest but will be considered only after intensive tests to determine their reliability under the severe surface conditions to be met.



Minitrack transmitter which sends signals from satellite to tracking stations. Mercury cells will power the transistorized unit for two weeks.

Telemetering Data: Data from the satellite's instruments will, according to early plans, be transmitted through the Minitrack transmitter. As the satellite approaches a ground station, a signal can be sent from a ground transmitter to a miniature receiver in the satellite. This signal would switch the Minitrack oscillator from the low-power Minitrack transmitter to a 0.5-w transmitter modulated by the telemetering system. After a fixed period of perhaps half a minute, a device in the satellite would de-energize the telemetering circuits and switch the antenna back to the low-power oscillator.

Tracking the Satellite: Two methods will be used to determine the satellite's course: a radio tracking method using the signal from the Minitrack transmitter, and optical tracking.

Optical tracking will be possible only when the satellite is in the sun and only when sky background is dark. In effect, this means only an hour after sunset or before sunrise for any observer.

The radio tracking method uses the phase difference between signals received at two antennas to determine position of the satellite. Two antenna systems at right angles will be used. Each set will consist of two main antennas 500 ft apart, plus lesser antennas to eliminate ambiguity in the measurement.

Differences in path length from the satellite to the antennas, as measured by a phase difference in the two signals received, establish an angular location with respect to the antenna base line. The second set of antennas at right angles establishes a unique direction in space from the observing site to the satellite.

Expected precision of operation is about 3 minutes of arc under normal conditions with improvement to about 20 sec of arc for observation at small zenith angles or under night time conditions. Data will be sent to a central computing facility within 20 minutes of receipt and used there for determining the satellite's orbit.

Instrumentation: Each satellite will be a specialized instrument, designed for one or a few specific experiments.

Some data will be obtained just by tracking the satellite. Atmosphere density might be deduced from measurement of the drag at orbital altitude. Improved measurements of the oblateness of the earth may be obtained. Distances between points on the earth's surface and differences in the earth's gravitational field could be calculated.

Miniaturized instruments have also been developed for certain experiments—for instance:

Pressure Gage: A bellows-actuated potentiometer to determine whether a meteorite punctures the satellite's skin. With a range of ±15 psi, the cylindrical gage is only 1 in. long, 1 in. in diameter and weighs 1½ oz.

Erosion Gage: A semitransparent Nichrome ribbon evaporated on glass. Mounted on the outside of the satellite's skin it will measure erosion caused by dust and micrometeorites. As the coating wears away, its resistance will increase.

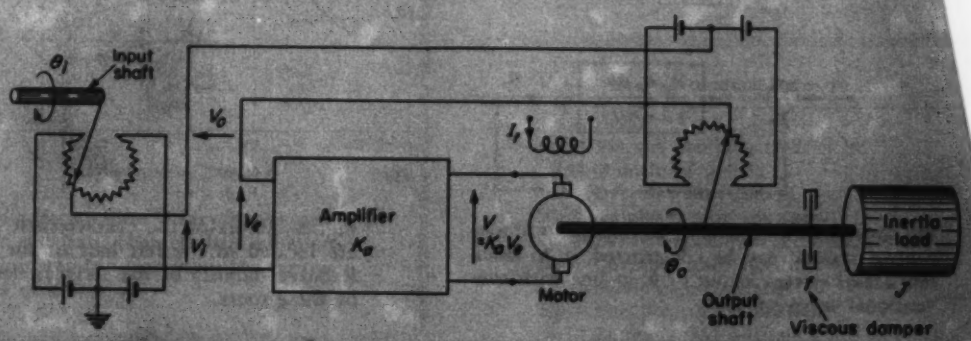
Temperature Gage: Semiconductor thermistors that can measure changes from −140 to 150 C.

Submeteoric Collision Microphone: A tiny microphone behind a sounding diaphragm on the surface of the satellite senses vibrations set up in the outer shell by small meteorites. A memory device stores the information until it can be transmitted.

Lyman-Alpha Equipment: Used to detect ionization produced by far ultraviolet solar-flare radiations through use of a peak memory unit. Information is stored for transmittal while telemetering.

Many other measurements are possible: the earth's magnetic field, cosmic and X-ray radiation, and so on. Final decision on which experiments will be conducted will probably be based on two factors: importance, and weight of the equipment.

Fig. 1—This simple position-control servomechanism is used to illustrate the application of servo theory to an actual system. Function of the system is simply to rotate the output shaft to the same position as that of the input shaft.



Analyzing Servo Systems

Two examples—a position control system and an engine governing system—show how transient response criteria are employed to determine performance.

By J. M. Nightingale
Manchester, England

TRANSIENT response criteria provide methods which are particularly suited to the analysis of relatively simple servo systems. Correspondingly, the equations of the system must be relatively manageable. A simple position control servomechanism and a speed-regulating system for a diesel engine will be analyzed in this article.

Previous articles have outlined the fundamental concepts of closed-loop control, briefly discussed the mathematics of control systems and outlined performance criteria.[1-4] This article illustrates the application of this material. In future articles more complex systems will be discussed. Then frequency-response techniques will be more suitable since the system equations are correspondingly more complicated.

Position Control Servo: Function of the position control system, Fig. 1, is to insure alignment between two shafts. Potentiometers attached to the input and output shafts give voltages which are proportional to the input and output displacements, respectively. These voltages are subtracted, and the difference between them gives a measure of error, or

$$V_e = V_i - V_o = \beta(\theta_i - \theta_o) = \beta e \qquad (1)$$

where the voltage-displacement ratios of the two potentiometers are taken to be equal and constant. This error voltage is then fed to an electronic amplifier.

The amplified voltage, $V = K_a V_e$, is then applied to a dc motor which gives a roughly proportional torque, thus

$$T = K_m V \qquad (2)$$

This torque in driving the output shaft is opposed by a load, which in this case is the result of an inertia J and a damper f. This load is inclusive of the inertia and mechanical resistance of the

[1]References are tabulated at end of article.

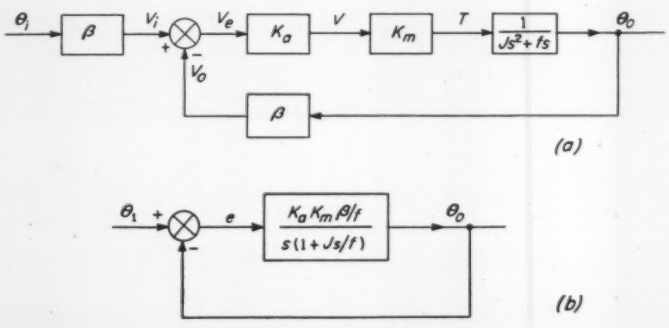


Fig. 2—Block diagrams of the simple position-control system may be constructed, *a*, to simulate actual system layout or *b*, in line with conventional servo practice.

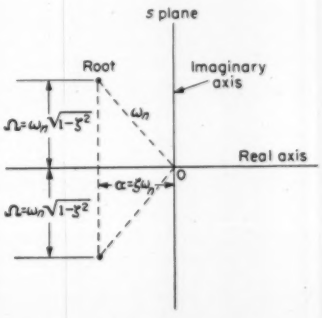


Fig. 3—Roots of the characteristic equation are located in the left half of the *s* plane. Relative stability of the servo is determined by these roots.

motor itself. Relationship between the output displacement, θ_o, and torque, T, is, therefore,

$$J\frac{d^2\theta_o}{dt^2} + f\frac{d\theta_o}{dt} = T \qquad (3)$$

Laplace transformation[2] of Equation 3, taking zero initial conditions, results in the transfer function,

$$\frac{\theta_o}{T}(s) = \frac{1}{Js^2 + fs} \qquad (4)$$

It is now possible to construct a block diagram for the complete system, Fig. 2*a*. This differs from the conventional block diagram of a closed-loop system in that quantities proportional to the output and input are subtracted at the differential, rather than the quantities themselves. If, however, the constants of the potentiometers are equal, then it is possible to redraw the diagram in the conventional manner, Fig. 2*b*. Here the potentiometer constant is included in the loop transfer function. This change is made purely to conform with normal practice in representing servos by block diagrams.

It can be seen that the loop transfer function is given by

$$\frac{\theta_o}{e}(s) = Y_o(s) = \frac{K}{s\left(1 + \frac{Js}{f}\right)} \qquad (5)$$

where $K = K_a K_m \beta/f$. Then the overall transfer function is given by

$$\frac{\theta_o}{\theta_i}(s) = Y_c(s) = \frac{Kf}{Js^2 + fs + Kf} \qquad (6)$$

In dealing with quadratic factors such as the denominator of the transfer function in Equation 6, it is very helpful to adopt a well-known notation. Then Equation 6 can be written as

$$\frac{\theta_o}{\theta_i}(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \qquad (7)$$

where

$$\omega = \sqrt{\frac{Kf}{J}} = \sqrt{\frac{K_a K_m \beta}{J}} \qquad (8)$$

$$\zeta = \frac{f}{\sqrt{4 K_a K_m \beta J}} \qquad (8a)$$

The servo system is absolutely stable provided f is positive. In order to determine its relative stability by transient response methods it is necessary to determine the roots of the characteristic equation. In this case the roots are located in the left half of the s plane as shown in Fig. 3.

Once the roots have been found, the response of the system to a unit-step function input can be found. The type of response depends on the value of ζ. If $\zeta > 1$ the response is purely exponential, but if $\zeta < 1$, the response also contains oscillatory components. Demarcation between the two types of responsible exists when $\zeta = 1$ and is called the *critically damped* case. Expressions for the response to unit step function input for various values of ζ are given in Table 1, while Fig. 4 plots these responses for numerical values of ζ.

In this application, K_a, the gain of the amplifier,

Table 1—Response to Unit Step Function Input

Values of ζ	Response Equation
>1	$\theta_o(t) = 1 - e^{-\zeta\omega_n t}\left[\cosh\gamma t + \frac{\zeta}{\sqrt{\zeta^2-1}}\sinh\gamma t\right]$
$=1$	$\theta_o(t) = 1 - e^{-\omega_n t}(1+\omega_n t)$
<1	$\theta_o(t) = 1 - e^{-\zeta\omega_n t}\left[\cos\Omega t + \frac{\zeta}{\sqrt{1-\zeta^2}}\sin\Omega t\right]$

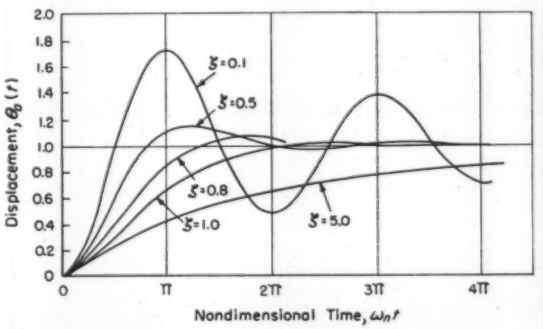


Fig. 4—Response of a servomechanism with a quadratic characteristic equation to a unit step-function input for various values of ζ.

is an easily adjusted parameter, and may be set to give optimum response. Often, $\zeta = 0.5$ is taken as the most desirable case. If this value is substituted in Equation 8a, K_a becomes

$$K_a = \frac{f^2}{K_m J \beta} \qquad (9)$$

In some applications, however, it may be necessary to have a more heavily damped response. For instance by choosing $\zeta = 0.8$, very little overshoot or oscillation is obtained, Fig. 4. This increased damping unfortunately results in a more sluggish response with a longer build-up time.

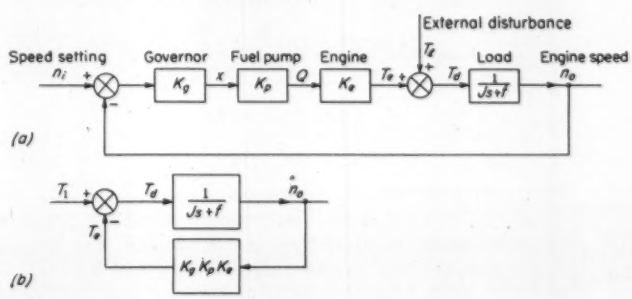
This servo is of the first order as shown by Equation 5. Therefore, it has zero steady-state positional error.[3] Here, however, positional accuracy really depends on the accuracy of the potentiometers. In response to a unit-velocity input, $U(t)t$, there is a steady following error of $1/K$. Thus the so-called velocity error can be reduced by increasing K_a, but here again improvement is achieved at the cost of reducing stability.

In most practical servos the equations will be complicated by time lags in the control equipment. Suppose that in the present case there is a time lag τ in the motor between the application of

Nomenclature

e = Error
f = Viscous damping coefficient
J = Moment of inertia
K = Overall gain constant
K_a = Amplifier gain constant
K_e = Diesel engine gain constant
K_g = Governor gain constant
K_m = Motor gain constant
K_p = Fuel pump gain constant
n_i = Engine speed setting
n_o = Actual engine speed
Q = Fuel supply rate
s = Laplace operator
T = Torque
T_e = Engine torque
T_l = Load torque
t = Time, variable
V = Voltage
x = Governor displacement
$Y_c(s)$ = Overall transfer function
$Y_o(s)$ = Loop transfer function
α = Real part of complex conjugate root $= \omega_n \zeta$
β = Voltage displacement constant of potentiometer
$\gamma = \omega_n \sqrt{\zeta^2 - 1}$ for $\zeta > 1$.
Δn_o = Speed droop
ΔT_l = Change in T_l
ζ = Damping ratio
θ_i = Input rotation
θ_o = Output rotation
τ = Time constant
Ω = Imaginary part of complex root $= \omega_n \sqrt{1 - \zeta^2}$ for $\zeta < 1$
ω_n = Modulus of complex conjugate root

Fig. 5—Block diagrams of a diesel-engine speed-control system may, *a*, incorporate blocks for all elements or, *b*, lump the characteristics of several elements in a conventional servo analysis fashion.



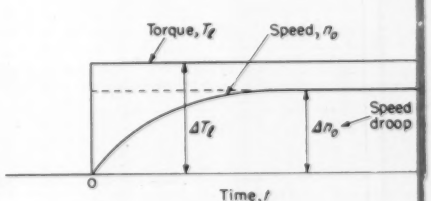


Fig. 6—A sudden change in external load on the diesel engine results in a small change in speed, the speed droop. Droop can be reduced by increasing K.

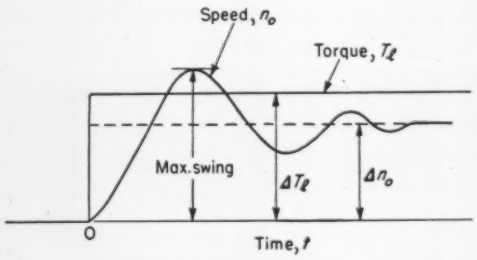


Fig. 7—Effect of time lags in the engine itself is to reduce the relative stability. Increasing K also tends to produce oscillation. Therefore, the value of K involves a compromise between speed droop and relative stability.

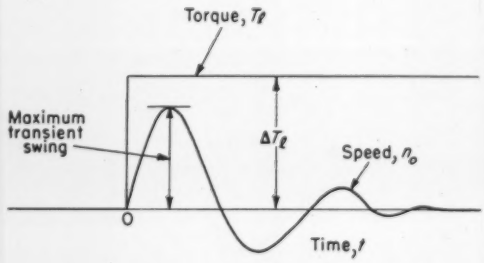


Fig. 8—When an isochronous governor is used, there is no steady speed droop. Transient behavior is dependent upon gain constant setting.

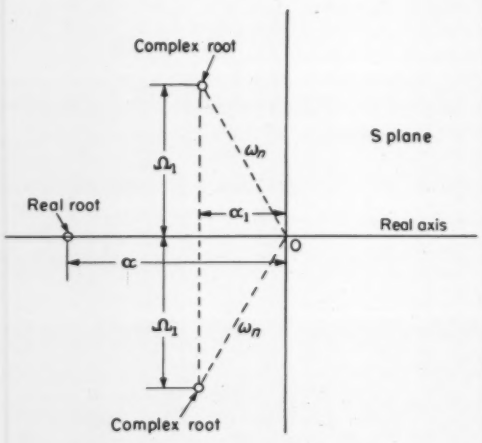


Fig. 9—Roots for the cubic characteristic equation of the isochronous governor must lie in the left half of the s plane for absolute stability. Suitable relative stability is insured by making $\alpha_1/\omega_n = 0.5$.

voltage V and the development of torque T. Mathematically this can be written

$$\frac{T}{V}(s) = \frac{K_m}{1+\tau s} \tag{10}$$

The loop and overall transfer functions of the complete system now become, respectively,

$$\frac{\theta_o}{e}(s) = \frac{K}{s\left(1+\frac{Js}{f}\right)(1+\tau s)} \tag{11}$$

$$\frac{\theta_o}{\theta_i}(s) = \frac{Kf}{[J\tau s^3 + (J+f\tau)s^2 + fs + Kf]} \tag{12}$$

The stability of the system is now dependent upon the magnitude of K. Also the increased complexity of the transfer functions makes analysis by transient response methods very tedious.

Diesel Engine Speed Regulator: In this system, Fig. 5*a*, the engine produces a torque, T_e, which is constrained by governor displacement, x. The governor itself is sensitive to the difference between the speed setting n_i and the actual engine speed n_o. Thus the constrained engine torque is

$$T_e = K_g K_p K_e (n_i - n_o) \tag{13}$$

Engine torque is opposed by an internal load torque plus an external load disturbance T_l. The torque equation is, therefore,

$$J\frac{dn_o}{dt} + fn_o = T_e + T_l \tag{14}$$

Function of the system is primarily to keep n_o substantially constant in the face of external load fluctuations. The response to change in speed setting n_i is of only secondary importance. Hence, by taking $n_i = 0$ (speed setting constant) the block diagram can be rearranged, Fig. 5*b*, to conform to conventions. Then

$$\frac{T_e}{T_l}(s) = \frac{1}{1+\frac{K}{Js+f}} \tag{15}$$

where $K = K_g K_p K_e$. It therefore follows that

$$\frac{n_o}{T_l}(s) = \frac{1}{Js+K+f} \tag{16}$$

This is the desired transfer function relating the engine speed to the external load. Stability is inherent.

Response to sudden change of load, ΔT_l, is shown in Fig. 6. The ultimate speed droop is given by

$$\Delta n_o = \frac{\Delta T_l}{K+f} \tag{17}$$

Thus ideally the droop can be diminished by making K very large. In practice, however, there will normally be time lags in the system. For example, suppose the engine response is given by

$$\frac{T_e}{Q}(s) = \frac{K_e}{1+\tau s} \tag{18}$$

The transfer function of the system is modified to

$$\frac{n_o}{T_l}(s) = \frac{1 + \tau s}{[J\tau s^2 + (J + f\tau)s + K + f]} \quad (19)$$

Now although the system is still unconditionally stable increasing K tends to decrease the relative stability, causing large overswings in the transient response, Fig. 7. Hence the ultimate choice of K must involve a compromise between droop and overswing requirements.

A well-known method for obtaining zero steady-state droop is to use an isochronous governor. Here the governor velocity rather than displacement is proportional to the speed change. Thus in transformed quantities

$$x = -\frac{K_g}{s} n_o \quad (20)$$

for $n_i = 0$. The transfer function for the system now becomes

$$\frac{n_o}{T_l}(s) = \frac{s(1 + \tau s)}{[J\tau s^3 + (J + f\tau)s^2 + fs + K]} \quad (21)$$

The denominator is now a cubic in s and as in Equation 12, stability now depends on the value of K. Routh's criterion for stability[3] gives

$$K \leqq \left(\frac{f}{J} + \frac{1}{\tau}\right) f \quad (22)$$

Although Equation 22 establishes a limiting value of K for absolute stability, K must be fixed at less than this value for a sufficiently damped system having suitable response characteristics.

The speed droop is (Theorem 8, Reference 2)

$$\Delta n_o = \Delta T_l \left[\frac{n_o}{T_l}(s)\right]_{s \to 0} \quad (23)$$

Substituting from Equation 21 in 23 shows that there is now no steady-state speed droop. Transient response to sudden load change now takes the form shown in Fig. 8. Amount of overswing depends on the damping of the oscillatory modes of the system. These modes are given by the roots of the characteristic equation, in this case

$$J\tau s^3 + (J + f\tau)s^2 + fs + K = 0 \quad (24)$$

In general this equation will have one real root and two conjugate complex roots. For stability these must all be located in the left-hand side of the s plane, Fig. 9. By choosing $\alpha_1/\omega_n = 0.5$ for the complex roots, suitable relative stability is insured. In terms of root location, the characteristic equation can be written as

$$J\tau[s^3 + (\omega_n + \alpha)s^2 + \omega_n(\omega_n + \alpha)s + \alpha\omega_n^2] = 0 \quad (25)$$

Then by equating coefficients of like powers of s in Equations 24 and 25 the root locations become

$$\left.\begin{aligned} \alpha &= \frac{J^2 + Jf\tau + f^2\tau^2}{J\tau(J + f\tau)} \\ \omega_n &= \frac{f}{J + f\tau} \end{aligned}\right\} \quad (26)$$

while the value of K is also determined, thus

$$K = \frac{f^2(J^2 + Jf\tau + f^2\tau^2}{(J + f\tau)^3} \quad (27)$$

with the roots of the characteristic equation, it is now possible to obtain an expression for the response to a sudden load change ΔT_l, thus

$$n_o(t) = \Delta T_l \left[Ae^{-\alpha t} + e^{-\omega_n t/2}\left(B\cos\frac{\sqrt{3}\,\omega_n t}{2} + C\sin\frac{\sqrt{3}\,\omega_n t}{2}\right)\right] \quad (28)$$

where A, B, and C are constants which can be found from a partial expansion of the transfer function, Equation 21.

Summary: It has been possible to treat both systems in this article by transient response methods because the assumptions made have kept the system equations fairly simple. As more complex systems are encountered it will be found that their analysis becomes tedious, if not extremely difficult, by transient response methods and frequency response techniques will have to be used. It is, therefore, desirable to be able to correlate frequency response results with the more easily understandable transient response curves.

REFERENCES

This article is the fifth in a co-ordinated group by J. M. Nightingale on servo systems. Previous articles, and the issues of MACHINE DESIGN in which they appeared, are:

1. "Automatic Control Systems" .....May 17, 1956
2. "Servo Mathematics" .....June 28, 1956
3. "Evaluating Servo System Performance—Part 1" July 26, 1956
4. "Evaluating Servo System Performance—Part 2" Aug.9, 1956

Tips and Techniques

Faster LeRoy Lettering

LeRoy lettering of capital letters can be accelerated by using one letter outline for more than one letter. For example, the letter *E* can also be used for *F*, *L* and *I*. Both *C* and *O* can be made using *O*. Central portion of *M* will serve for *V*. Letters *J* and *U* can be made from *U*, and *P* may be formed from *R*.—D. J. COLOCCIA, *Wheeler Laboratories Inc., Great Neck, N. Y.*

Graduated Ruling Pen

Inked line widths can be closely duplicated by graduating the thumb nut on a ruling pen or compass. A piece of paper pasted to the thumb nut is divided into as many equal segments as possible and the center line of the pen or compass used as the index. Such graduations will also facilitate fine adjustment of dividers.—LEROY PAYNE, *Lockheed Aircraft Corp., Burbank, Calif.*

A PAPER FROM THE
THIRD CONFERENCE ON MECHANISMS

Practical approaches to

DESIGNING to utilize the full advantage of cams requires consideration and balancing of many factors. This discussion covers four specific aspects: (1) Timing charts, (2) cam manufacture, (3) types of cams in general use, and (4) design for wear.

Timing Charts

The machine-timing diagram provides the designer with visual means for establishing the time-displacement relationship of the key parts in a complex machine. If the movements of these parts are produced by cam-driven mechanisms, the designer can control, within reasonable limits, the time interval of operation of each movement, and select its motion characteristic—that is, harmonic, sinusoidal, etc.

The development of the timing chart for a machine begins with a crude diagram similar to that shown in Fig. 1*a*. In this diagram the extremities of each proposed movement are connected by a straight line, and arbitrary scales of displacement are used. As the design of the machine progresses and each mechanism is conceived and analyzed, changes in time and displacement are made to satisfy the operating conditions. Eventually, as shown in Fig. 1*b*, there is constructed a timing diagram showing the position of each significant element at any time during the machine cycle. The extremities of each movement are now connected by a curved line representing a reasonable approximation of the displacement characteristic. The displacements may be derived graphically or mathematically.

Significance of Short Strokes: A follower mechanism may have more than one forward or return stroke of unequal but similar displacement characteristic. The relationship of the working periods to maintain equal maximum inertia force is

$$\theta_1 = \theta \left(\frac{S_1}{S} \right)^{1/2}$$

where θ and θ_1 are the respective working periods

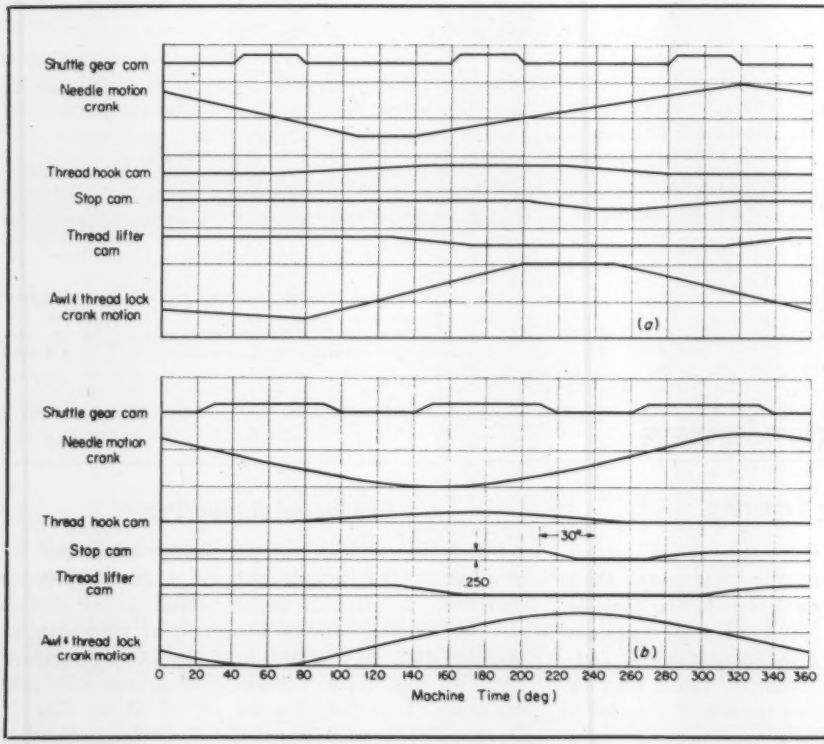


Fig. 1—Two stages in the evolution of a timing diagram for a machine. Diagram at *a* shows a typical first approach; at *b*, refinements have been included and the final functions are shown rather precisely.

CAM DESIGN

By W. D. Cram, *Mechanical Engineer*
Research Div., United Shoe Machinery Corp., Beverly, Mass.

for the long stroke S and the shorter stroke S_1. For example, if the 0.250-in. displacement shown in Fig. 1*b* were preceded by a displacement of 1.0 in. with a similar motion characteristic, and a working period of 80 deg, then the time interval t for the 0.250-in. displacement should be 40 deg to avoid greater inertia forces during the shorter stroke.

No design is complete without an investigation of the vibratory forces which occur during and after each stroke. For cam-driven mechanisms with the same period of free vibration and motion characteristic, these forces will, in general, increase with a decrease in operating time. Since, in the previous example, the time interval for the 0.250-in. stroke is one half of that for the 1.0-in. stroke, additional operating time may be required for the lesser stroke to avoid cam failure due to the higher vibratory forces.

Overlapping of Motions: In complex machines, the total cyclic time is divided among many mechanisms some of whose motions may overlap one another; that is, more than one mechanism is in motion at the same time.

When this occurs, the amount of overlap will depend on the operating clearance which can be tolerated between moving parts. The effect of a change in overlap on the working period will depend on the motion characteristics of the particular mechanisms involved. Excessive inertia and dynamic forces in a mechanism are often avoided by reducing the operating clearance. This is best illustrated at the extremities of a stroke where a small change in the position of the working tool can produce an appreciable increase in operating time.

Among the common continuous cam curves, the greatest increase in operating time is produced by the cycloidal curve. For example, assume that the time interval of 30 deg for the 0.250-in. displacement shown in Fig. 1*b* could be increased to tolerate 4 per cent of the total stroke, or 0.010-in. displacement at the stroke extremities. If the motion characteristic were harmonic, then, as shown in Fig. 2 the time interval would be in-

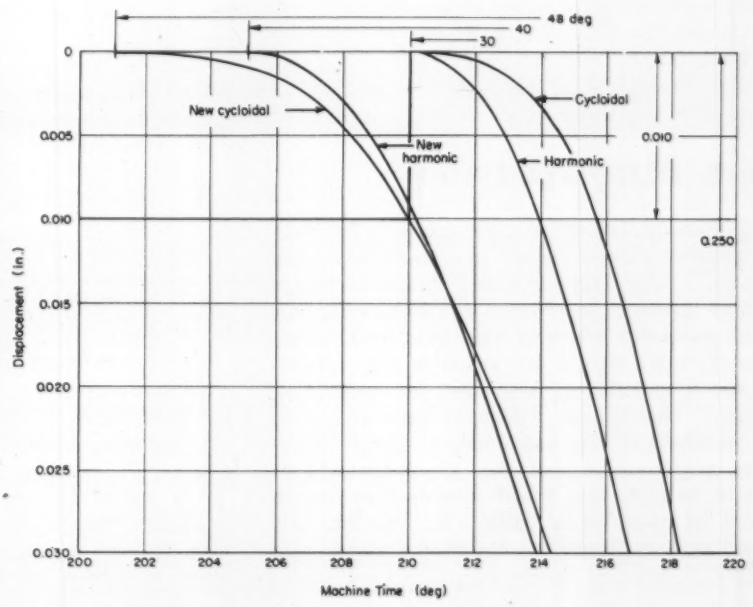


Fig. 2—Plot comparing gains in machine time obtained by allowing 4 per cent of the 0.250-in. total displacement, or 0.010-in., to occur after start of next machine sequence. In this example of overlapping motions, the cycloidal shows a gain of 8 deg more than the harmonic, and resulting maximum inertia force with the cycloidal is 88 per cent that with the harmonic.

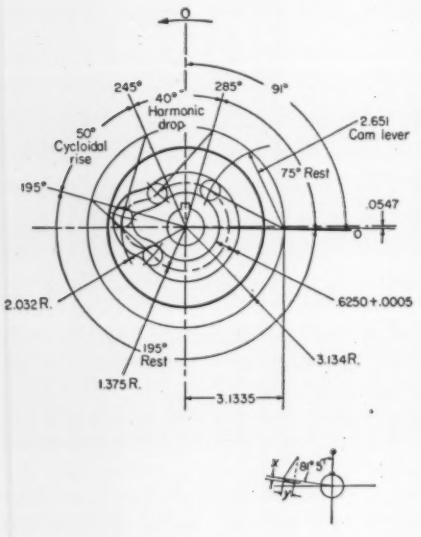


Fig. 3—Typical detailed cam drawing.

Leader No. 5792: 0.657-in. throw in 50 deg, cycloidal
0.657-in. throw in 40 deg, harmonic

Deg.	Y	X	Deg.	Y	X	Deg.	Y	X
81°5′	0	0	112°5′	.4792	.0160	51°5′	.5611	.0102
82°5′	0	0	113°5′	.5013	.0146	52°5′	.5422	.0118
83°5′	.0003	0	114°5′	.5222	.0132	53°5′	.5219	.0133
84°5′	.0009	.0001	115°5′	.5417	.0116	54°5′	.5000	.0148
85°5′	.0022	.0003	116°5′	.5594	.0101	55°5′	.4780	.0161
86°5′	.0042	.0005	117°5′	.5760	.0086	56°5′	.4545	.0173
87°5′	.0072	.0009	118°5′	.5908	.0072	57°5′	.4303	.0184
88°5′	.0114	.0014	119°5′	.6039	.0059	58°5′	.4054	.0192
89°5′	.0168	.0020	120°5′	.6154	.0047	59°5′	.3800	.0198
90°5′	.0235	.0028	121°5′	.6251	.0036	60°5′	.3543	.0202
91°5′	.0318	.0038	122°5′	.6334	.0026	61°5′	.3285	.0203
92°5′	.0417	.0048	123°5′	.6402	.0018	62°5′	.3027	.0212
93°5′	.0531	.0061	124°5′	.6456	.0012	63°5′	.2770	.0198
94°5′	.0662	.0074	125°5′	.6497	.0007	64°5′	.2516	.0192
95°5′	.0810	.0088	126°5′	.6528	.0003	65°5′	.2267	.0183
96°5′	.0973	.0103	127°5′	.6548	.0002	66°5′	.2025	.0173
97°5′	.1153	.0126	128°5′	.6561	.0002	67°5′	.1790	.0160
98°5′	.1348	.0133	129°5′	.6567	.0002	68°5′	.1565	.0147
99°5′	.1556	.0147	130°5′	.6569	.0002	69°5′	.1351	.0132
100°5′	.1778	.0161	131°5′	.6570	.0002	70°5′	.1148	.0116
101°5′	.2010	.0173	195° Dwell			71°5′	.0959	.0100
102°5′	.2250	.0184	41°5′	.6570	0	72°5′	.0784	.0084
103°5′	.2504	.0192	42°5′	.6560	.0001	73°5′	.0625	.0068
104°5′	.2761	.0198	43°5′	.6530	.0005	74°5′	.0482	.0054
105°5′	.3022	.0202	44°5′	.6480	.0011	75°5′	.0357	.0040
106°5′	.3285	.0203	45°5′	.6410	.0019	76°5′	.0249	.0028
107°5′	.3548	.0199	46°5′	.6321	.0030	77°5′	.0160	.0017
108°5′	.3810	.0198	47°5′	.6213	.0042	78°5′	.0091	.0009
109°5′	.4066	.0191	48°5′	.6087	.0056	79°5′	.0040	.0003
110°5′	.4317	.0183	49°5′	.5945	.0070	80°5′	.0010	.0001
111°5′	.4560	.0172	50°5′	.5785	.0086	81°5′	0	.0001

creased from 30 to 40 deg or by 33 per cent, and the inertia forces reduced 44 per cent. If the motion were cycloidal, the time interval would be increased from 30 to 48 deg or 60 per cent, and the inertia forces reduced 61 per cent. The maximum inertia force for the cycloidal motion would be 88 per cent of the maximum inertia force for the harmonic motion. Of perhaps even greater significance would be the lower vibratory forces obtained with the cycloidal motion, as reported in the literature on cam dynamics.

Cam Manufacture

The manufacture of precision gears is basically a generating process. Since gear teeth have cam surfaces, it is conceivable that a similar technique could be developed to produce precision cams. Although numerous attempts have been made to accomplish this, there is not available for commercial use a satisfactory universal cam-generating machine. Hence, cam designers must resort to other methods of cam manufacture. Several techniques are available, but this discussion will be confined to plate-cam leader manufacture by the method of co-ordinate pairs. At present, this method appears to produce the most accurate cam profile.

Preparation of Data: The linear displacements, machine times, and common timing reference (or "zero") of the various mechanisms in a machine, are contained in the basic time chart. From this information, the follower roll positions for each cam stroke are determined and with their corresponding machine times are recorded on a detailed cam drawing similar to that shown in Fig. 3.

The master cam leader manufacturing data are then calculated and tabulated as shown in Fig. 3. This table includes the co-ordinate displacements of the center of the follower roll for each degree of rotation of the leader. It is also customary to provide the manufacturing department with an illustration which shows the initial position of the cutting tool with respect to a reference, such as a keyway, common to the other cams in the machine.

Manufacture: The leader blank is fastened to an indexing table mounted on a jig borer or other suitable equipment, and machined from the tabulated data.

The general procedure is to rough-cut the blank, leaving approximately 0.020-in. of material for the finishing cut. This step-by-step process creates a leader with a finely scalloped surface, and hand finishing is necessary to remove these asperities. The height of the ridges will depend on the interval of angular displacement of the blank and its diameter, the cutter diameter, and the increment displacement. For example, for the cam shown in Fig. 3, the ridge height varies from zero at the start of each stroke to a maximum of approximately 0.002-in. at the midpoint of the cycloidal motion.

To facilitate this operation, and to maintain parallelism of the finished surface with the axis of rotation, the master cam leader thickness is made 5/16-in. or less. From this master leader there is made on a copying machine a manufacturing leader whose profile is duplicated on the production cams.

Complementary or conjugate cams require modified manufacturing techniques. An economical procedure is to make two leaders, one for the cam and one for the conjugate. A timing hole, common to both leaders and both cams, is used to maintain angular relationship of the cam and the conjugate.

A more accurate but costlier method is to make the cam from a leader in the usual manner and to rough cut the conjugate to within 0.015 to 0.020-in. of its finished profile. Then, as shown in Fig. 4, the cam and its lever are mounted on a fixture attached to a vertical milling machine. The fixture straddles an index head whose spindle passes through the fixture, and the cam is fastened to the index-head spindle. The conjugate cam roll is replaced by a milling cutter of equal diameter which, as the cam is rotated, generates the conjugate profile. To minimize the effect of machine deflections due to severe cutting loads, two and sometimes three milling operations are necessary. For each succeeding operation, a larger-diameter cam roll is mounted in the cam lever.

Calculating Co-ordinate Values: The discussion of cam leader calculations includes two methods for determining the co-ordinates of the four types of follower construction shown in Fig. 5.

When manufacturing leaders by the method of co-ordinate pairs, it is customary to calculate the X and Y co-ordinates by the radius-vector method in which the ordinate or Y axis is represented by a line drawn from the center of the cam to the center of the cam roll at its outer-most position, and the abscissa or X axis is normal to the Y axis at the extreme position of the roll center.

The equations used for the calculation of the X and Y co-ordinate values by the radius vector method are derived from the geometry of Fig. 6 and are listed there. The follower displacement characteristic — harmonic, cycloidal, polynomial, etc.—is represented by $f(t)$.

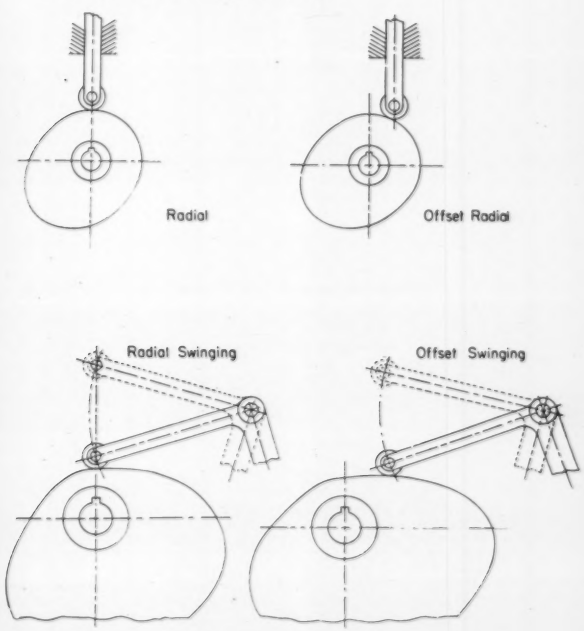
A simpler method for determining the co-ordinate values has been devised. Essentially, simplification is obtained by eliminating the use of radius vector values in the calculations.

The equations used in calculating the X and Y co-ordinate values are shown in Fig. 7 and are derived from the geometry of Fig. 7.

With the exception of the radial-follower solution, the reduced number of computations for calculating the X and Y values by this method requires less than one half of the time needed for the radius-vector method when conventional

Fig. 4—Set-up for final machining of one conjugate cam from its finished mate.

Fig. 5—Four types of cam and follower arrangements. Alternate calculation procedures are detailed in Figs. 6 and 7.



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desk calculators are used.

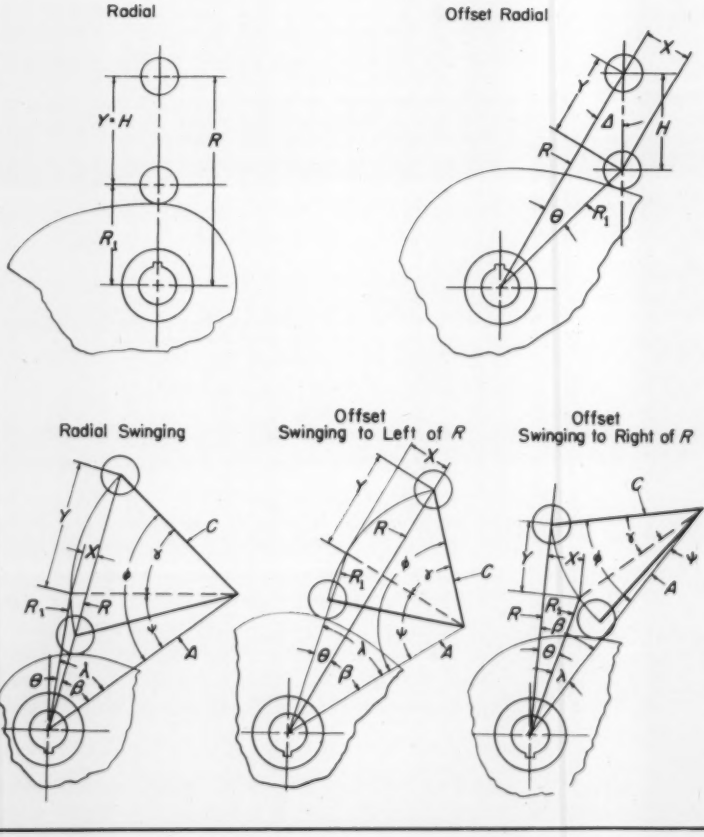
The time required to produce X and Y values with digital computers is exceedingly short. For example, the co-ordinates for a particular cam leader were determined with a conventional desk calculating machine in 16 hours for a simplified solution, whereas the same values were obtained from a digital computer in 10 minutes. Obviously, there is very little difference in calculating time between the radius vector and simplified methods when a digital computer is used. However, programming and flow-chart preparation are less complicated and time consuming for the simplified solution.

Profile Accuracy: A comparison between actual and theoretical profiles is difficult to obtain, principally because no equipment equivalent to that used for measuring profile errors of gears has been developed. However, cam leaders manufac-

Nomenclature

H = Any linear displacement of follower, in.
R = Distance from center of cam to center of follower roll at its outermost position, in.
R_1 = Distance from center of cam to center of follower roll at any position of arm, in.
Δ = Angle between H and R, deg
C = Length of follower arm, in.
A = Distance from center of cam to center of rotation of follower arm, in.
ϕ = Angle between A and C when follower is at its outermost position, deg
γ = Any angular displacement of arm, deg
β = Angle between R and A, deg
λ = Angle between R_1 and A, deg
Y = Distance from extremity of R, parallel to R, to any position H or γ of follower roller center; or the vertical cam leader co-ordinate, in.
X = Distance from extremity of R, perpendicular to R, to any position H or γ of follower roller center for corresponding distance Y; or the horizontal cam leader co-ordinate, in.

Fig. 6 — Radius-vector method of calculating co-ordinates.



Radial

$H = f(t)$

$R_1 = R - H$

$X = 0$

$Y = R - R_1 = H$

Offset Radial

$H = f(t)$

$R_1 = \sqrt{R^2 + H^2 - 2RH\cos\Delta}$

$\theta = \cos^{-1}\dfrac{R^2 + R_1^2 - H^2}{2RR_1}$

$X = R_1 \sin\theta$

$Y = R - R_1\cos\theta$

Radial Swinging

$\gamma = f(t)$

$\psi = \theta - \gamma$

$R_1 = \sqrt{A^2 + C^2 - 2AC\cos\psi}$

$\lambda = \cos^{-1}\dfrac{R_1^2 + A^2 - C^2}{2R_1A}$

$\theta = \lambda - \beta$

$X = R_1\sin\theta$

$Y = R - R_1\cos\theta$

Offset Swinging to Left of R

$\gamma = f(t)$

$\psi = \theta - \gamma$

$R_1 = \sqrt{A^2 + C^2 - 2AC\cos\psi}$

$\lambda = \cos^{-1}\dfrac{R_1^2 + A^2 - C^2}{2R_1A}$

$\theta = \lambda - \beta$

$X = R_1\sin\theta$

$Y = R - R_1\cos\theta$

Offset Swinging to Right of R

$\gamma = f(t)$

$\psi = \theta - \gamma$

$R_1 = \sqrt{A^2 + C^2 - 2AC\cos\psi}$

$\lambda = \cos^{-1}\dfrac{R_1^2 + A^2 - C^2}{2R_1A}$

$\theta = \beta - \lambda$

$X = R_1\sin\theta$

$Y = R - R_1\cos\theta$

tured by the step-by-step or co-ordinate method have been compared with leaders produced by the template and numerical control methods, and found to have greater profile accuracy.

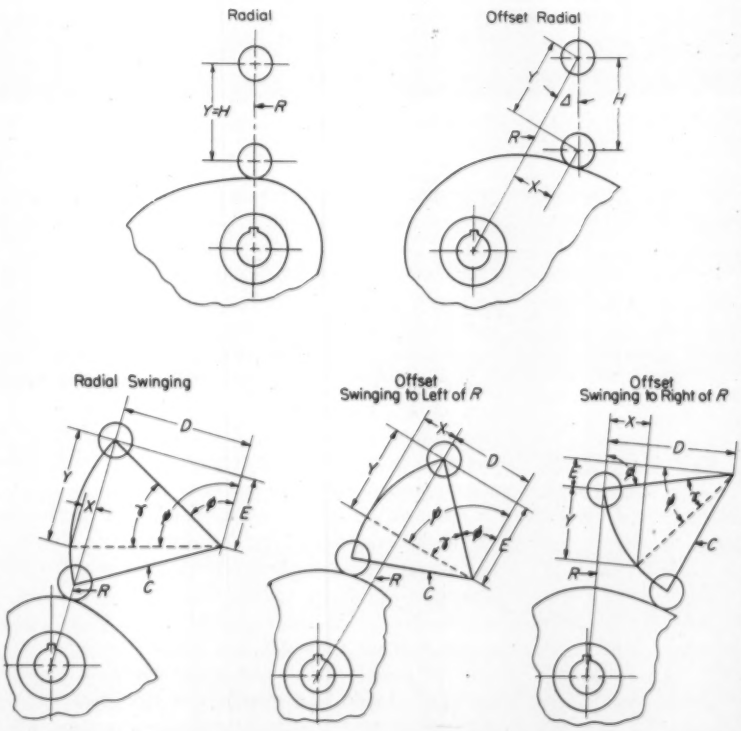
The importance of profile accuracy does not wholly lie in the total deviation from the theoretical profile. Also important are the increment deviation and its proportion to the theoretical change in increment displacement. For example, an error of 0.001-in. at the beginning of a stroke, where the increment change in displacement is small, is of more concern than the same error at the middle of the stroke where the increment change is much larger. Also, the effect of a gradual error occurring over a long period is less important than the same total error in a much shorter period.

Surface Finish: The surface finish of cams and leaders made from Austempered alloy cast iron and medium-carbon steel heat-treated before machining is not critical for rolling contact conditions. With ductile materials, surface irregularities *yield* readily to contact pressure. Therefore, sufficient area of contact is maintained to support applied loads. Obviously, if the initial surface finish is exceedingly rough, premature surface failure can occur. Therefore, an average finish of 100 rms or less is recommended for cams made from the aforementioned materials. When cams made of these materials operate within their surface-endurance limits, there is a definite improvement in surface finish and hardness. From actual roll tests of SAE 4150 steel heat-treated before machining to 270-300 Bhn and phosphate coated, the surface

Fig. 7—Simplified method of calculating co-ordinates.

Nomenclature

H = Any linear displacement of follower, in.
R = Distance from center of cam to center of follower roll at its outermost position, in.
Δ = Angle between H and R, deg
C = Length of follower arm, in.
γ = Any angular displacement of arm, deg
ϕ = Angle between R and C when follower is at its outermost position, deg
D = Distance from R, perpendicular to R, to the center of rotation of the follower arm, in.
E = Distance from extremity of R, parallel to R, to the center of rotation of the follower arm, in.
Y = Distance from extremity of R, parallel to any position H or γ of follower roller center; or the vertical cam leader co-ordinate, in.
X = Distance from extremity of R, perpendicular to R, to any position H or γ of follower roller center for corresponding distance Y; or the horizontal cam leader co-ordinate, in.



Radial

$H = f(t)$
$X = 0$
$Y = H$

Offset Radial

$H = f(t)$
$X = H \sin \Delta$
$Y = H \cos \Delta$

Radial Swinging

$\gamma = f(t)$
$\psi = \phi + \gamma$
$X = C \sin \psi - D$
$Y = E - C \cos \psi$

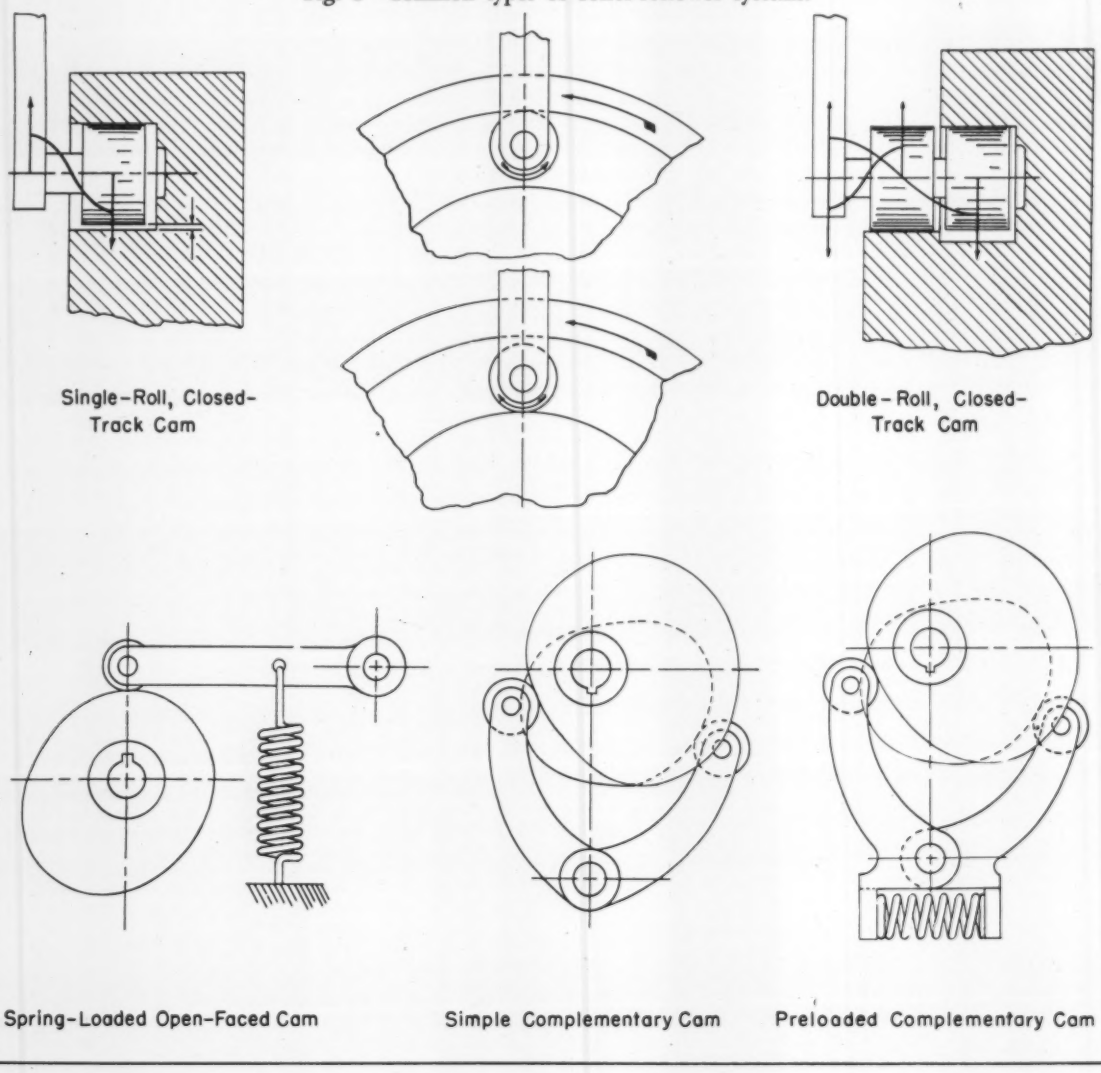
Offset Swinging to Left of R

$\gamma = f(t)$
$\psi = \phi + \gamma$
$X = C \sin \psi - D$
$Y = E - C \cos \psi$

Offset Swinging to Right of R

$\gamma = f(t)$
$\psi = \gamma + (90 - \phi)$
$X = D - C \cos \psi$
$Y = C \sin \psi - E$

Fig. 8—Common types of roller-follower systems.



finish measured on a Brush Surface Analyzer was reduced from 100 rms average to 25 rms average, and the hardness increased by 100 points Brinell approximately. When prehardened steels are used for cams, the surface finish is extremely important. Since these materials have little ductility, local surface stresses can be high enough to cause premature failure.

Common Types of Cams

To produce motion of reciprocation or oscillation, there are two systems in general use: (1) the crank-link mechanism or four-bar linkage and (2) the cam-controlled mechanism.

From experience, the simple four-bar linkage has definite superior operating characteristics. Its load-carrying capacity is greater, it can operate at faster speeds, it is quieter and smoother in operation, and it generally costs less. Unfortunately, the single four-bar linkage lacks one feature which restricts its use; there is no dwell period in this type of motion. Combinations of four-bar linkages can be designed with simulated dwell periods. However, these combinations are complex and costly, and are seldom used for producing intermittent motions. On the other hand, cam-controlled mechanisms are ideally suited for this purpose.

Recent studies and investigations of cam profiles and cam dynamics have provided comprehensive knowledge of the influence of these factors in cam design. Since little information is available on the types of cams in general use, it is intended to comment briefly on the merits and deficiencies of cams with roller type followers. For simplicity, the discussion is limited to the constructions shown in Fig. 8.

Single-Roll Closed-Track Cam: This construction is simple and used extensively in machines in which loads and speeds are moderate.

Limited face width, overhung mounting of the cam roll and operating clearance between cam roll

and cam track combine to render it unsuitable for high speeds and heavy loads.

Because of the overhung mounting of the cam roll, the lever is subjected to an eccentric load which results in a twisting moment. This introduces a torsional deflection of the lever which changes the position of the cam roll on the cam, thereby decreasing the length of the contact between these two members, and consequently reducing their load-carrying capacity.

In operation, when the cam roll has attained its maximum velocity, it is urged by the energy stored in the follower system during the period of acceleration to leave one side of the track and contact the other with an impact whose force may be several times that of the maximum inertia force of the follower system. This impact force promotes abnormal cam loads and objectionable noise.

When the roll shifts from one side of the track to the other, its direction of motion changes from clockwise to counterclockwise, or vice versa. This introduces sliding between the cam and roll, and between the roll bearing and its support. The sliding results in a scuffing action which tends to break down the cam surface, and the sudden reversal of motion may cause damage to the bearing elements.

Double-Roll Closed-Track Cam: This construction is designed to minimize clearance between cam and roll and permit singular rotation of the cam rolls. It has successfully replaced the conventional single-roll closed-track cam on many machines.

Its load-carrying capacity is limited by the practical face width of either roll, and it is also vulnerable to the effects of misalignment between cam and roll.

Spring-Loaded Open-Face Cam: This type of cam is also used to offset the deficiencies of the single-roll closed-track cam. Good contact between the cam and roll is maintained by straddle-mounting the roll which rotates in one direction only; wider faced cams of smaller diameter are practicable and operating clearance is eliminated.

However, there are some disadvantages to this construction. Since the spring deflection is directly proportional to the follower displacement, the maximum force due to spring deflection will occur at the completion of the follower stroke, and not at or near midstroke where the follower has attained its maximum velocity and tends to leave the cam surface. Consequently, surface stresses and cam shaft torques are redundant.

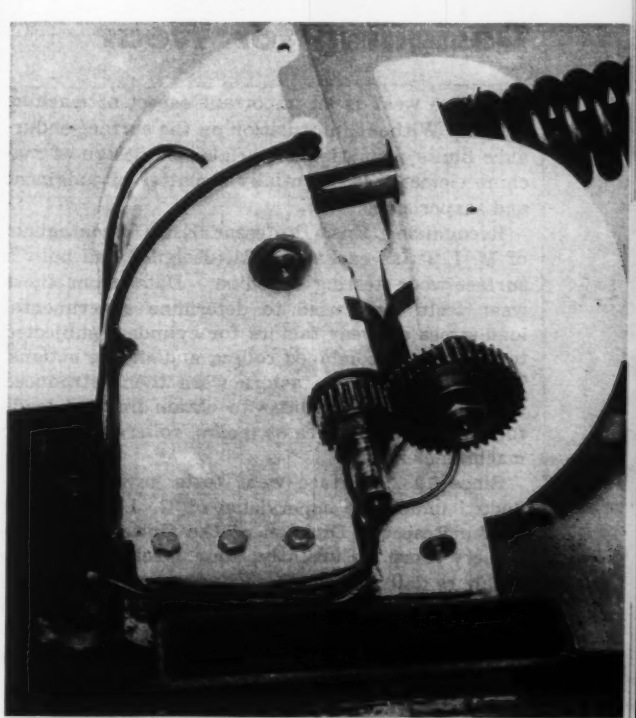
Spring characteristics are important, especially stiffness, which must be sufficient to avoid surging due to resonance between the cam operating speed and one of the natural frequencies of the spring. This precludes the use of low-scale springs for high-speed applications.

Objectionable cam shaft torques due to a combination of preload and pressure angle may be encountered in applications where manual rotation of the cam shaft is desirable to permit adjustment of related parts and to study their sequence of operation.

Simple Complementary Cams: This type is more costly than any of the other types previously mentioned. Theoretically, no separation should take place between the cams and their rolls because the distance between the cam roll centers is designed to be constant for all positions of the cam. Unfortunately, present manufacturing techniques are unable to cope with clearances due to assembly and manufacturing tolerances, and to dynamic deflections. Until clearance is eliminated, these cams will operate with objectionable noise at high speed. When some backlash can be tolerated, complementary cams can support heavier loads than other types of cams.

Preloaded Complementary Cams: When over-all clearances are small, preloading of complementary cams to eliminate play can be accomplished by using ball bearings as cam rolls. Their inherent flexibility permits safe deflections of low magnitude. When clearance is greater than the permissible deflection of the ball bearings, the cam levers can be separated and then spring connected. In

Fig. 9—Roll-testing machine for obtaining basic wear data.



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operation, the spring deflection is independent of the stroke and proportional to the working clearance; therefore, cam mechanisms with large strokes may be preloaded, spring stiffness can be high, and spring surge should be negligible.

The preload will depend on the dynamic forces in the follower system and may also depend on the working or applied loads. When resistance is applied in one direction only, the system can be designed to have that load transferred directly to the cam. When resistances are offered to both forward and return motion of the cam lever, the preload must be increased to oppose one of these resistances.

As stated previously, in the conventional spring-loaded open-faced cam system, the preload, necessary to maintain contact between cam and roll, may produce excessive cam loads and cam shaft torques.

With preloaded complementary cams, the preload will be nearly constant for all positions of the follower and will be less than the maximum preload required in the open-faced cam system. The predominant cam-shaft torques due to the preload can be significantly reduced by designing the system so that the torques due to the preload between the cams and their rolls oppose each other.

In addition, correct preloading eliminates separation and resultant impact forces, thus permitting more accurate prediction of cam life.

In contrast to the other constructions, the preloaded conjugate cam system is more complex and costly, and its lubrication requirements can be more critical.

Designing for Wear

Surface wear is an important aspect of machine design. Without information on the surface-endurance limits of mating materials, the design of machine elements is essentially a matter of judgment and experience.

Recognizing this, Professor Earle Buckingham of M. I. T., as early as 1931, designed and built a surface-wear testing machine. Data from these wear tests were used to determine experimental load-stress or wear factors for cylinders subjected to rolling and combined rolling and sliding actions. These experimental factors were then introduced into appropriate formulas to obtain limiting loads for surface wear of cams, gears, rollers, and other machine elements.

Since 1932, surface wear tests have been conducted under the supervision of G. J. Talbourdet at the Research Division of the United Shoe Machinery Corp. Currently, four machines operate 24 hours daily, at the Beverly plant. Considerable data have been accumulated and made available to design engineers in progress reports. The most recent report is paper 54-LUB-14, presented by Mr. G. J. Talbourdet at the ASME-ASLE Lubrication Conference in Baltimore on Oct. 18-20, 1954. The information contained in that paper and in the publications listed in its bibliography provide knowledge of the surface-endurance limits of engineering materials and also aid recognition and understanding of the types of failures common to machine elements.

The present testing machine with its cover removed is shown in Fig. 9. The test rolls are mounted on gear-driven arbors, one of which is supported in a fixed frame, the other in a pivoted frame. Load is applied through a calibrated spring connecting the two frames. The rolls and their supporting bearings are amply lubricated with a straight mineral oil of 280-320 SSU at 100F. For rolling contact, the surface velocity of the test rolls is 600 fpm.

From actual roll tests it was found that for rolling contact of metallic materials, the rapidity of the stress cycle had no appreciable influence on the surface-endurance limits of these materials. However, for nonmetallic materials, such as laminated phenolics, the surface fatigue depends on the rapidity as well as the number of cycles. That is, the faster the speed of operation, the lower the number of cycles for surface failure. This is due to the large elastic deformation, high internal friction and poor heat conductivity of phenolics.

The gear ratio and test roll diameters are changed to suit specific test conditions for combined rolling and various percentages of sliding.

Combined rolling and sliding mean that the mating rolls are subjected to simultaneous rolling and sliding actions. The rate of sliding, or sliding velocity, is equal to the difference in surface velocities of the mating cylinders and varies with the speed of operation. For example, if all the rolls shown in Fig. 10 were made to operate at 1200 rpm, the sliding velocity would be increased to 628.32 fpm.

On the other hand, the percentage sliding is equal to the ratio of the sliding velocity to the surface velocity of either test roll and is independent of the speed of operation. For example, if the rotational speed of the four specimens shown in Fig. 10 were again assumed to be 1200 rpm, the percentage sliding would remain unchanged. The percentage sliding on each specimen of a combination will be different, and can vary from zero for rolling contact to infinity for gross sliding. The percentage sliding is a ratio and is independent of speed. Therefore, the experimental load-stress factors determined from roll tests for combined rolling and sliding actions can be used in the expression for the limiting safe wearing load between cam and roll, when similar sliding conditions are present. However, when sliding exists, the problems of heat dissipation, sparking and surface welding must be considered in the design, and these factors become more critical as the rate of sliding is increased.

The experimental load-stress factor for mating materials is determined from the loads applied on the test rolls and the radii of curvature of the rolls. This factor is expressed, by definition, as

$$K = \frac{p}{L}\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

where K = experimental load-stress factor, per inch of contact; p = limiting surface wear load on test rolls, lb; L = length of contact between rolls, in.; r_1 and r_2 = radii of test rolls, in.

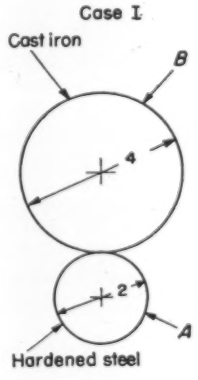
The basic Hertz equation for the maximum specific compressive stress between two external cylinders within the elastic limit of their respective materials is

$$S_c^2 = \frac{0.35p\left(\frac{1}{r_1} + \frac{1}{r_2}\right)}{L\left(\frac{1}{E_1} + \frac{1}{E_2}\right)}$$

where S_c = maximum specific compressive stress, psi; E_1 and E_2 = moduli of elasticity of rolls r_1

Fig. 10—Demonstration of significance of sliding between rolls.

Assume speed of all specimens equal to 600 rpm.



Case I

Rate of sliding $= V_B - V_A$

$$= \frac{600\,\pi}{12}(4 - 2)$$

$$= 314.16 \text{ fpm}$$

Percentage sliding on $A = \frac{V_B - V_A}{V_A}$

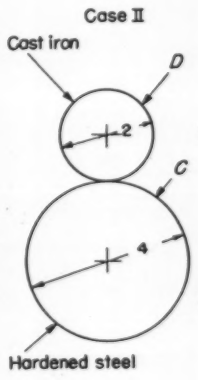
$$= \frac{314.16}{314.16}$$

$$= 100 \text{ per cent}$$

Percentage sliding on $B = \frac{V_B - V_A}{V_B}$

$$= \frac{314.16}{628.32}$$

$$= 50 \text{ per cent}$$



Case II

Rate of sliding $= V_C - V_D$

$$= \frac{600\,\pi}{12}(4 - 2)$$

$$= 314.16 \text{ fpm}$$

Percentage sliding on $C = \frac{V_C - V_D}{V_C}$

$$= \frac{314.16}{628.32}$$

$$= 50 \text{ per cent}$$

Percentage sliding on $D = \frac{V_C - V_D}{V_D}$

$$= \frac{314.16}{314.16}$$

$$= 100 \text{ per cent}$$

Significance

Rate of sliding is the same in both cases, but percentage sliding is different for similar materials.

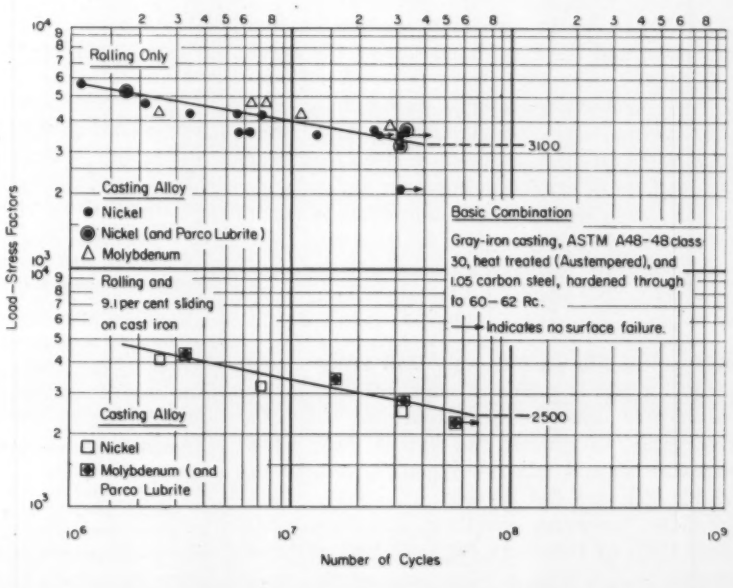
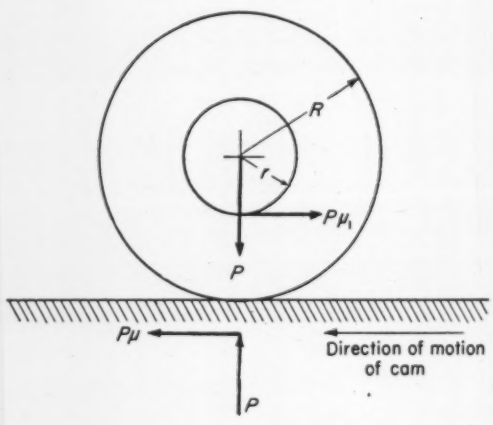


Fig. 11—Typical load-life data for rolls tested in equipment shown in Fig. 9.



Friction moment tending to rotate cam roll $\approx PR\mu$.
Friction moment opposing rotation of cam roll $\approx Pr\mu_1$.
Nomenclature: P = applied load; R = radius of cam roll; r = radius of cam roll stud; μ = coefficient of rolling friction between cam and roll; μ_1 = coefficient of sliding friction between cam roll and cam roll stud.

Fig. 12—Forces acting on follower roll.

and r_2, respectively, psi.

This equation can be transformed to read

$$\frac{S_c^2\left(\frac{1}{E_1}+\frac{1}{E_2}\right)}{0.35} = \frac{p}{L}\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$$

With this arrangement, the left-hand side of the equation is constant for a given combination of materials, and the right-hand side of the equation is equal to the load-stress factor K. Therefore, if the load-stress factor is known for a combination of materials, the limiting surface wear load for any two cylinders with a given length of contact can be determined. For cam and roll applications the following simple expression is used:

$$P = \frac{KL}{\left(\frac{1}{R_1} \pm \frac{1}{R_2}\right)}$$

where P = limiting surface wear load between cam and roll, lb; R_1 = radius of cam roll, in.; R_2 = radius of curvature of cam contour, in. When the cam curvature is convex, the sign is plus; when concave the sign is minus. When R_2 is infinite, as with a roll on a flat surface, $P = KLR_1$.

From the foregoing equations, the importance of large radii of curvature for both cam and roll is evident.

As illustrated in Fig. 11, when one of the mating materials is a ferrous ductile material, no surface breakdown should be expected after approximately 40 million cycles of repeated stress for rolling conditions. For combined rolling and sliding conditions, the number of repeated cycles of stress beyond which no surface breakdown will occur depends on the percentage sliding. For hardened steel materials subjected to rolling only, the number of cycles may be as high as 500 million.

Table 1 gives a list of experimental load-stress factors at 100 million cycles of repeated stress for combinations of materials subjected to rolling contact. Also given are some factors for combined rolling and sliding; the sliding is 9 per cent on the first material and 8.3 per cent on the second of each combination.

For numbers of cycles other than 100 million, load-stress factors can be interpreted from load-life charts similar to that shown in Fig. 11. As can be seen in Fig. 11, the load-life curve represents probable values. Exact load-stress factors, therefore, may be greater or less than those listed. In addition, tests are generally conducted under optimum conditions which are not encountered in service. Therefore, it appears logical that factors of safety should be considered when determining

Table 1—Experimental Load-Stress Factors at 100 Million Cycles

Both Rolls of Same Material	Sliding (%) 0	9
Gray-iron casting, ASTM A48-48 Class 20, 130-180 Bhn	1300	1050
G.M. Meehanite, 190-240 Bhn	1950	1500
Nodular-iron casting, ASTM-A339-51T, Grade 80-60-03, 207-241 Bhn	3400	1850
Gray-iron casting, ASTM A48-48, Class 30, heat treated (Asutempered), 270-290 Bhn	4200	3400
One Roll: Tool steel, 1.05 carbon, hardened through to 60-62 Rc		
Other Roll:		
Gray-iron casting, ASTM A48-48, Class 20, 160-190 Bhn, phosphate coated	1300	....
Gray-iron casting, ASTM A339-51T, Grade 20, 140-160 Bhn	1000	900
Nodular-iron casting, ASTM A339-51T, Grade 80-60-03, 207-241 Bhn	2000	1750
Gray-iron casting, ASTM A48-48, Class 30, 200-220 Bhn	1600	....
Gray-iron casting, ASTM A48-48, Class 35, 225-255 Bhn	2300	2100
Gray-iron casting, ASTM A48-48, Class 30, heat treated (Austempered) 255-300 Bhn	3100	2500
SAE 1020 steel, 130-150 Bhn	1700	1350
SAE 4150 steel, heat treated to 270-300 Bhn, phosphate coated	12,000	7900
SAE 4150 steel, heat treated to 270-300 Bhn	9000	6700
SAE 1020 steel, carburized to 0.045-in. depth of case, 50-58 Rc	13,000	8500
SAE 1340 steel, induction hardened to 45-55 Rc	10,000	8000
SAE 4340 steel, induction hardened to 50-55 Rc	13,000	9000
High-strength yellow brass, extruded	2000	....
Zinc die casting	320	260
Random-fiber cotton-base phenolic	1000	950
NEMA Grade L, laminated phenolic	880	830
Linen base, laminated phenolic	800	700
Graphitized laminated phenolic	1000	....

the safe wear load capacity of cams.

Cam designs involving combined rolling and high-percentage sliding actions should be very carefully engineered. As the percentage sliding increases, the value of the load-stress factor decreases. The lubrication factor which depends on the sliding velocity becomes important, and the operating efficiency is reduced because of the high tangential forces of sliding friction at the surface contact.

On the other hand, when the contacting surfaces are subjected to rolling only, load-stress factors and operating efficiency are maximum, and heat of operation and lubrication requirements are minimum.

Cam Rolls: If possible, cam rolls should be straddle-mounted and supported by antifriction bearings to maintain rolling contact.

Careful consideration should be given to designs in which journal-bearing cam rolls are used. Here the turning moment due to rolling friction between cam and roll must be greater than the resisting moment caused by sliding between the cam-roll stud and its bearing as shown in Fig. 12. To obtain rolling contact on dwell periods, the ratio of roll diameter to stud diameter should be greater than the ratio of sliding friction between roll and stud to rolling friction between cam and roll.

Obviously, the load-carrying capacity of the cam-roll bearing must be greater than the maximum load imposed on the cam and roll surfaces. When ball bearings are used as cam followers, the outer race is unsupported and manufacturers should be consulted for load-carrying capacity. Generally, when the radius of the cam roll is approximately equal to one-third of the radius of curvature of the cam, the bearing capacity will be equal to approximately one-third of the catalog rating for quiet-running radial loads.

Lubrication: The cam-roll bearing must be lubricated to maintain rolling contact. For rolling contact conditions, intermittent lubrication of the cam surface with ordinary machine oil will prevent corrosion and dispose of particles of metal which may be sheared off the cam surface. However, for preloaded cam systems and for high-speed designs in which the rate of sliding may be high, lubrication of the cam surface may also be necessary to prevent sparking, surface welding and to dissipate the heat generated in operation. In these applications, method and type of lubrication are important. In some instances, surface welding and sparking can be eliminated by contaminating the cam surface with phosphate coating (Parco-Lubrite). In others, where combinations of high loads and high sliding velocity are present, it may be necessary to use extreme-pressure lubricants containing additives of chlorine or sulphur. The use of grease, semifluid grease and other highly viscous lubricants is not recommended. The inherently high friction resistance of these lubricants may promote sliding of the cam roll on the cam surface. Furthermore, their tendency to hold sheared-off metal particles is objectionable, because these particles, in turn, can cause abrasive wear of the cam surface.

Loading: Cam-driven mechanisms require at least a superficial analysis to ascertain the type and magnitude of loading to be resisted by the cam and roll surfaces. The forces which can be imposed on the cam and roll are of several types:

1. Accelerating or inertia forces
2. Vibratory forces
3. Impact forces
4. Working or applied loads
5. Friction forces

The inertia forces are a product of the mass and acceleration of the follower system. Variations in inertia forces create vibrations which produce vibratory stresses in the follower system. These stresses account for vibratory forces between cam and roll. The magnitude of these forces is influenced by the acceleration characteristics, elasticity, and damping of the follower mechanism. Other conditions being equal, sinusoidal acceleration patterns appear to produce the lowest magnitude of vibratory force among the common continuous functions.

Impact forces are caused by separation due to clearance between the cam and roll surfaces.

Working loads represent the useful work done by the mechanism. Their application may augment or reduce the other forces in the system. For example, if applied during the forward cam stroke, they add to the inertia forces during the accelerating period. During the decelerating period, they diminish impact and vibratory forces by absorbing some of the energy stored in the follower mechanism.

Friction forces may or may not oppose inertia forces but do help to dampen vibratory forces.

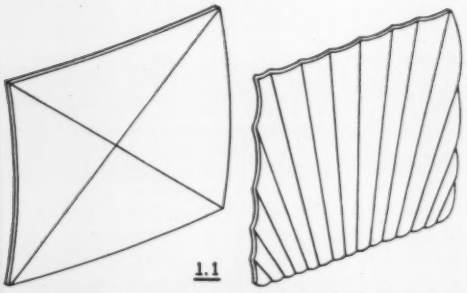
Pressure angle, misalignment, surface finish, and accuracy of cam contour are other factors which must be considered when designing for wear.

From this discussion, it should be evident that the force analysis of a cam-driven mechanism can be diversified and complex. There is no established procedure for ascertaining the magnitude of loading to be resisted by the cam and roll surfaces. The different combinations of factors which can contribute to the loading necessitate individual analysis of each cam problem.

This article was presented as a paper at the Third Conference on Mechanisms, Purdue University, May 24-25, 1956. The Conference is cosponsored annually by the Purdue School of Mechanical Engineering and MACHINE DESIGN. Copies of the 38-page *Transactions* containing the five formal Conference papers are available for $1.00 each from: Reader Service Dept., MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

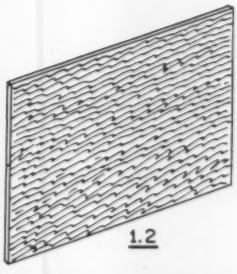
XUM

Fig. 1 Flat Surfaces



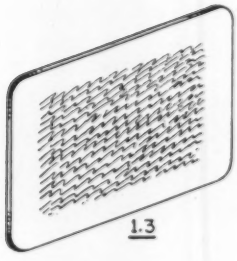
1.1

Simple 5 to 10-degree bends formed in a press brake stiffen panel when it is forced flat. Edges should be confined, covered, or flanged for maximum results and best appearance.



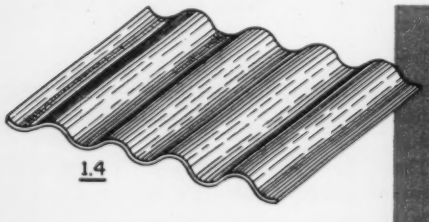
1.2

Embossed sheet metal is available in a wide variety of gages, patterns and finishes. Recommended for light-duty decorative applications.



1.3

If a clear space is desired around the edge of a part, the center may be embossed with dies. The patterns should be simple: either straight parallel ridges or a light knurled effect.



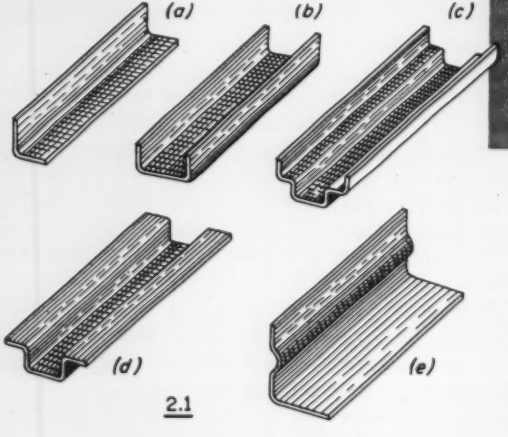
1.4

Where appearance is not a factor, and rigidity is required in only one direction, corrugated sheet may be employed.

Strengthening

TWO of the chief advantages of sheet metal stampings are their relatively low cost and lightweight. To utilize these advantages fully, stampings must be designed so they may be produced inexpensively and require minimum material. Since raw material cost of a stamping is always a considerable percentage of the total cost, stampings should always be designed to use the thinnest material possible. Obviously, there is a practical limit to this reduction of thickness

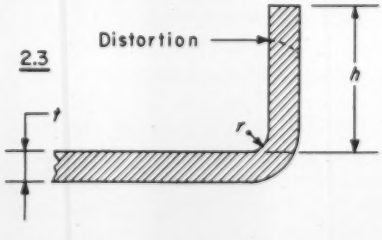
Fig. 2 Long, Narrow Parts



2.1

For long parts where longitudinal strength is desired, various combinations of flanges may be employed, Figs. 2.1 through 2.2. Do not specify full 90-degree bends with close tolerances, since gage tolerances, die design and wear, and tensile strength of material combine to produce springback which is very expensive to control precisely. Fig. 2.2 represents a half-round which has good strength and is inexpensive to form.

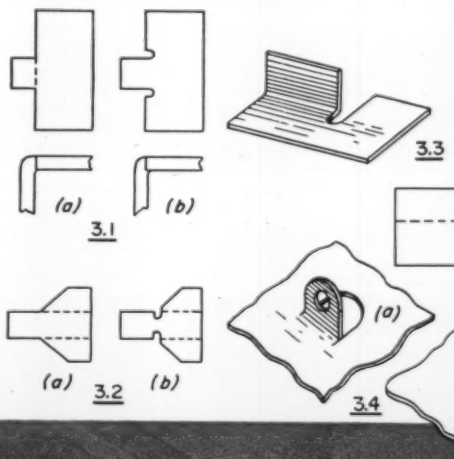
2.2



2.3

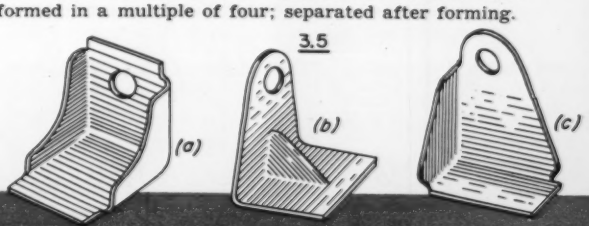
For practical flanges, radius r should be 1 to 2 times metal thickness. To avoid distortion of flanged edge and rapid die wear, h should be $2t$ to $4t$, but in no case less than $\frac{1}{8}$-in.

Fig. 3 Brackets



Bends should not end at sharp corners, as in Fig. 3.1*a*. Provide a relief pocket, Fig. 3.1*b*, or move bend line at least 2*t* out on tab, away from internal corners. A similar condition is shown in Fig. 3.2*a* and 3.2*b*, with *b* as desired practice to eliminate tearing of part and rapid die wear. When a bend terminates in the middle of a part, Fig. 3.3, a slot should be used. Tabs are sometimes lanced from a sheet, Fig. 3.4, but tears will start at the end of the cut if any strain is applied. Fig. 3.4*b* represents better practice.

Brackets can be reinforced considerably by use of side flanges, Fig. 3.5*a*, or ribs, Fig. 3.5*b*. Design of Fig. 3.5*c* is applicable when parts are made in right and left-hand units. This bracket is blanked and formed in a multiple of four; separated after forming.



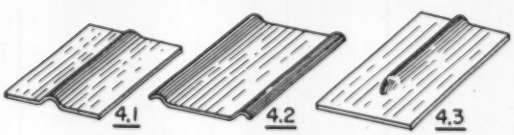
Metal Stampings

By Federico Strasser,
Santiago, Chile

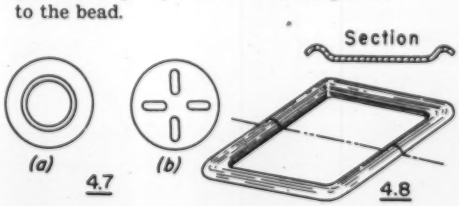
because weakness and flexibility, which may be objectionable, are increased as the metal becomes thinner. However, employment of thin-gage metal, judiciously reinforced with beads, ribs and flanges, frequently yields substantial savings and still retains functional ability.

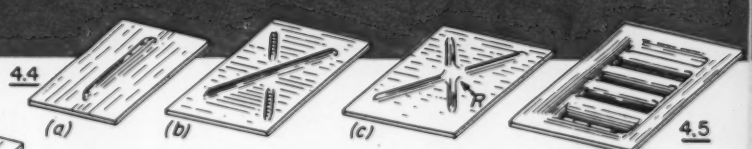
Frequently, for small production items, heavy material is employed rather than lighter, reinforced parts because of apparent tooling costs. However, simple forms of reinforcing, such as flanges and bends, are widely used when only one or two pieces are required. Even more involved strengthening devices in light-gage metal will yield to properly-designed short-run tooling. Reinforcing flanges, bends, fluting and corrugations are widely used on one-of-a-kind jobs; for instance, in sheet-metal air duct panels and cabinet and wall panels. These are usually designed to combine utilitarian strengthening with improved appearance. Pre-embossed metal, available ready to be

Fig. 4 Large Panels

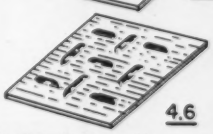


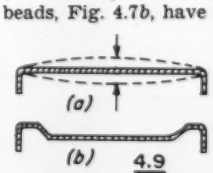
Large panels are commonly reinforced with beads. Fig. 4.1 shows an open-end center bead, Fig. 4.2 edge beads, and Fig. 4.3 a central bead with one closed end. In each case, the direction of greatest rigidity is, of course, parallel to the bead.





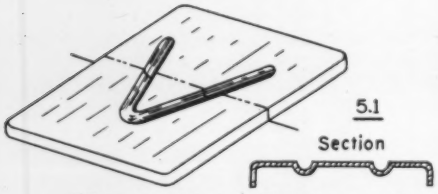
Various common applications of beads are illustrated. Preferably, beads are nonintersecting, as in Fig. 4.4*b*. However, frequently the greater rigidity offered by intersecting beads, Fig. 4.4*c*, will justify the more expensive die construction. Radius *R*, Fig. 4.4*c*, at the intersection should be at least twice total bead width. Parallel beads as in Fig. 4.5 may be on one side of the normal plane, or on both sides. In either case, the ratio of height to width should be low to avoid wrinkling of edge of panel when beads are formed. For round parts, beads should be in the form of circles, Fig. 4.7*a*. Straight beads, Fig. 4.7*b*, have negligible stiffening value.



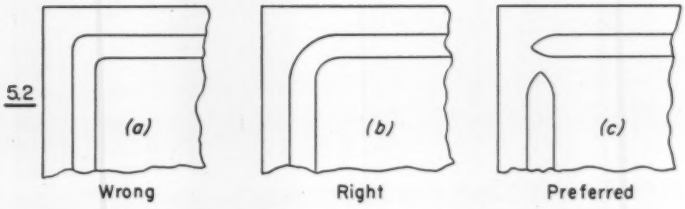


If the center is flat, a bead may be formed around the edge, Fig. 4.8, or a flange, Fig. 4.9. A flange frequently leaves excess metal in the center giving a "dish-pan" effect. This can be eliminated by depressing the center, Fig. 4.9*b*.

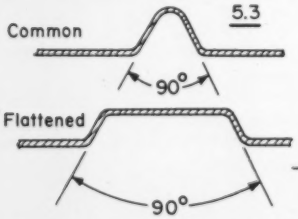
Fig. 5 Beads



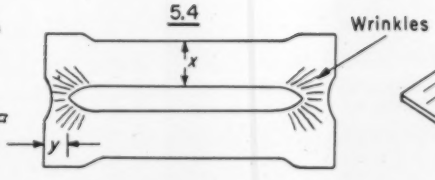
Where beads and flanges are combined, both should project on the same side of the metal for most economical die design.



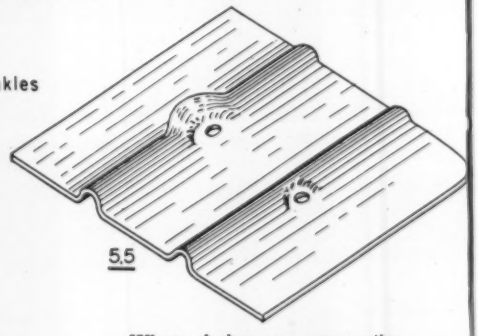
Sharp corners as Fig. 5.2*a* are liable to tear metal. so beads should always intersect with liberal radii, Fig. 5.2*b*. Nonintersecting beads, Fig. 5.2*c* are generally as strong and are less expensive to produce.



Beads are of two general types: common and flattened. Both usually have sides at a 90-degree angle. Radii should be 2 to 6 times metal thickness. Normally, flattened bead width is 4 times the height.

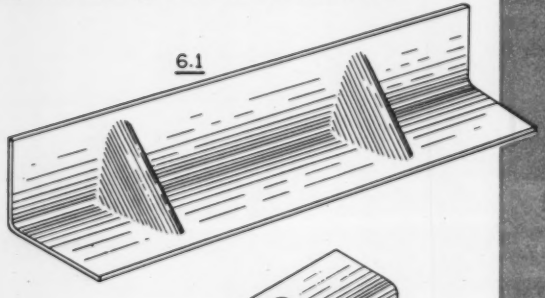


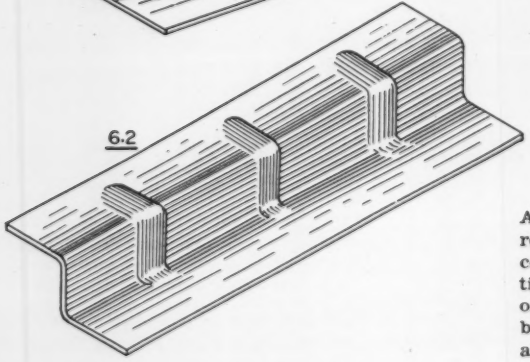
Due to the stretching of metal involved, some wrinkling may occur at ends of beads. To avoid distortion of the edge of the metal, distance x should be at least $40t$ and distance y should be $25t$. If the edge is flanged, these distances may be reduced to $a = 30\text{-}35t$, $b = 15t$, minimum values.



Where holes are near ribs, to avoid severe distortion the holes are pierced after the ribs are formed. Good practice is to dislocate or reduce the bead near the hole location.

Fig. 6 High-Strength Construction





Extremely strong parts may be produced by a combination of beads, ribs, and flanges.

used and inherently very rigid in relation to its thickness, is also widely used for low-production decorative items. Other strengthening media are primarily high-production devices due to the tooling required. These include closed beads and ribs, flanges on curved parts, and combinations of flanges and ribs. The more useful strengthening media are given in the accompanying illustrations, approximately in order of increasing tool requirements, and therefore approximately in order of increasing production requirements for economical employment.

A common design for reinforcing a bolted cover used in conjunction with a gasket demonstrates use of flange, beads, and beads around holes.

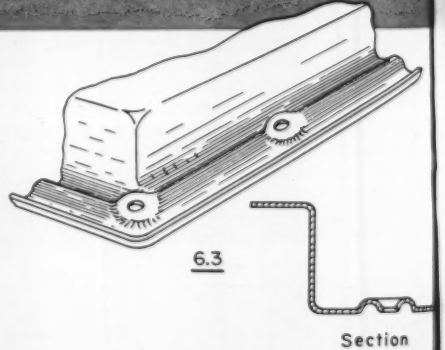
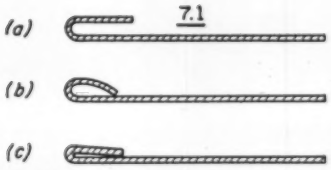
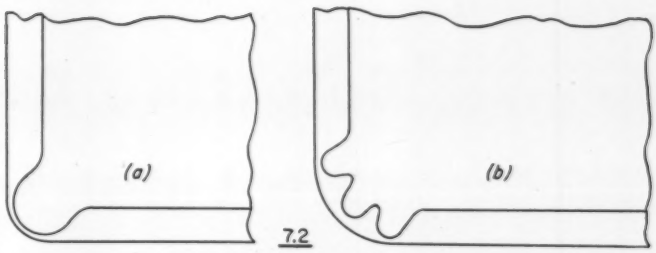


Fig. 7 Edge Treatments



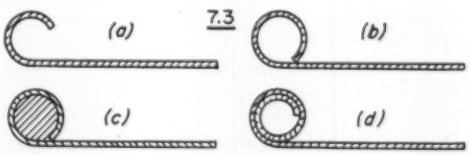
7.1

Hemming is a common edge treatment. Forms shown at *a* and *b* are normal and will frequently be produced in the same die due to material variations and die wear. Fig. 7.1*c* is a flattened hem which should be avoided due to the greater tonnage required and the more severe working of the metal.



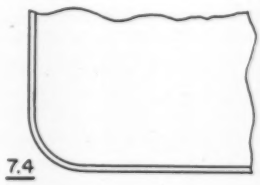
7.2

Where a rounded corner is hemmed, the material to be folded should be reduced, Fig. 7.2*a*, or notched, Fig. 7.2*b*, to eliminate wrinkles.

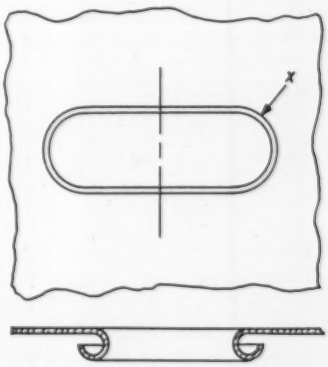


7.3

Figs. 7.3*a* and 7.3*b* illustrate open and closed curls produced in dies very similar to hemming dies but frequently requiring one more operation. For extremely light material the curl may be formed over a wire. Fig. 7.3*c* or double curled, Fig. 7.3*d*.

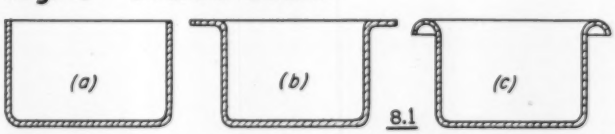

7.4

In contrast to hemmed edges, curls will normally form around a corner, Fig. 7.4, without wrinkling. However, when formed around a hole as in Fig. 7.5 commonly used for hand-holes, the metal may tear at *x*.



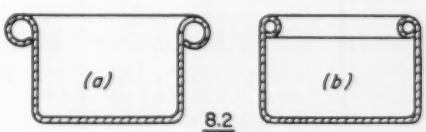
7.5

Fig. 8 Drawn Shells

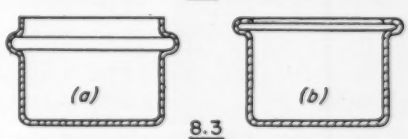


8.1

The upper edges of drawn cups, Fig. 8.1*a*, may be strengthened in a number of ways. Illustrated are a flange, *b*, open hem, *c*, outside curl, Fig. 8.2*a*, inside curl, *b*, and bulged beads in Fig. 8.3. The metal on the side of a cup is severely compressed and work hardened. Therefore, inside curls, as in Fig. 8.2*b*, should be avoided since they require additional compression. Bulges, Fig. 8.3, should be near the open end of the cup where more metal is available.



8.2



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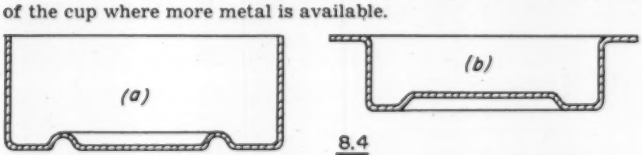
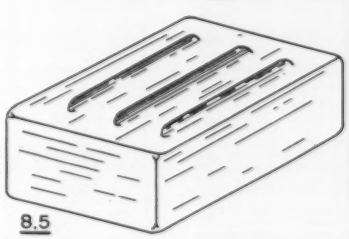


8.4

The bottom of large-diameter drawn shells is frequently subject to "dish-panning." This may be eliminated by beads or depressions. Bottoms of large rectangular shells are reinforced, similar to regular panels, with beads, Fig. 8.5.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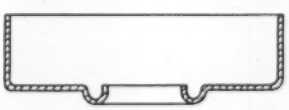
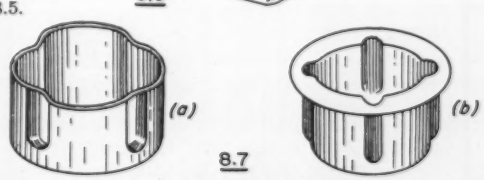

8.6

The edge of a hole in the bottom of a drawn shell may be beaded for reinforcement.



8.7

Side walls of shells may be reinforced parallel to their length by beads or fluting, alone or in combination with flanges.

Selecting Gear Ratio with Limit Stops

By Max Fogiel, *Control Instrument Co. Inc.*
Div. of Burroughs Corp., Brooklyn, N. Y.

IN INSTRUMENT drives it is often necessary to connect a mechanical limit. stop into the system. This poses a problem as to the gear ratio which should be provided between the motor and the limit stop. The general tendency is to make the ratio high in the belief that this will reduce the speed of the limit stop shaft and hence keep the impact force to a minimum value.

Often, however, the high gear ratio will multiply the torque of the motor to the extent that it will destroy the limit stop even though impact is negligible. Under such circumstances, a somewhat lower gear ratio is often selected on an intuitive basis with the hope that the impact force will be at a minimum without destroying the limit stop through the application of high torque values.

For any actual installation, there is an optimum gear ratio for which the forces tending to distort the limit stop will be at a minimum.

When all the shaft rotations are stopped by the limit stop, the kinetic energy of the system goes toward distorting the limit stop. Assuming elastic action, a maximum distorting force at the stop equal to F_1 and a deformation at the stop equal to S, the kinetic energy is:

$$\tfrac{1}{2} F_1 S = E \qquad \text{or}$$

$$F_1 = \frac{2E}{S}$$

The distorting force also has a component F_2 which is proportional to torque T_l applied by the motor through the gearing to the limit stop shaft. Since the work performed by the torque is $T_l\theta$, where θ represents the angular shaft rotation corresponding to the linear distance S,

$$\tfrac{1}{2} F_2 S = \tfrac{1}{2} T_l \theta \qquad \text{or}$$

$$F_2 = \frac{T_l \theta}{S}$$

The total distorting force is

$$F = F_1 + F_2 = \frac{2E}{S} + \left(\frac{\theta}{S}\right) T_l$$

The kinetic energy of the system is

$$E = \tfrac{1}{2} \left(I_m \omega_m^2 + I_l \omega_l^2\right)$$

where I_m represents the inertia of the motor and gearing reflected to the motor shaft, and I_l is the inertia at the limit stop.

Assuming the gear ratio N between motor and limit stop,

$$\omega_l = \frac{\omega_m}{N}, \quad T_l = NT_m$$

then the total force on the limit stop is

$$F = \frac{1}{S}\left(I_m \omega_m^2 + I_l \frac{\omega_m^2}{N^2}\right) + \left(\frac{\theta}{S}\right) NT_m \qquad (1)$$

To find the gear ratio N which will make F a minimum,

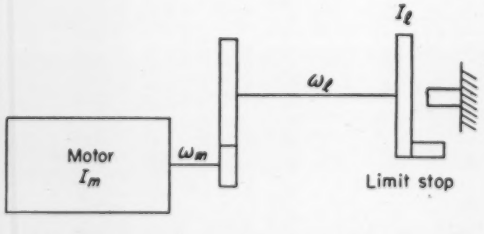
$$\frac{dF}{dN} = \frac{1}{S}\left(\frac{-2I_l \omega_m^2}{N^3}\right) + \left(\frac{\theta}{S}\right) T_m = 0$$

Therefore the gear ratio is

$$N = \sqrt[3]{\frac{2I_l \omega_m^2}{\theta T_m}} \qquad (2)$$

Angle θ may be interpreted as the permissible angular deflection of the limit stop shaft. Equation 2 shows that with a high-torque motor, the gear ratio should be low. These observations check with the intuitive reasoning indicated in the second paragraph.

Although motor inertia does not appear in the equation for optimum gear ratio, it is, of course, an important factor in determining actual total force on the limit stop, as Equation 1 shows.



Rotation of motor-driven system is to be stopped by limit stop. Article tells how to figure gear ratio between motor and stop for minimum distorting force at stop.

By Raymond Meyer
Griscom-Russell Co.
Massillon, Ohio

Gasketing of

Flanged Connections

for ultrahigh-pressure service

Flanged connections designed for 10,000 psi tube pressure using soft gasket concept. Tubing is 1.9 in. OD and 1 in. ID.

PROCESS piping and equipment are now being built to handle pressures of 10,000, 20,000, or 50,000 psi. Piping is available in yield strengths of 125,000 psi and up, and with improved associated design, these ultrahigh pressures can be used in hydrogenation, ammonia, and similar processes. This article is concerned chiefly with flanged connections for pressures above 10,000 psi, an area that may be labeled as ultrahigh pressure.

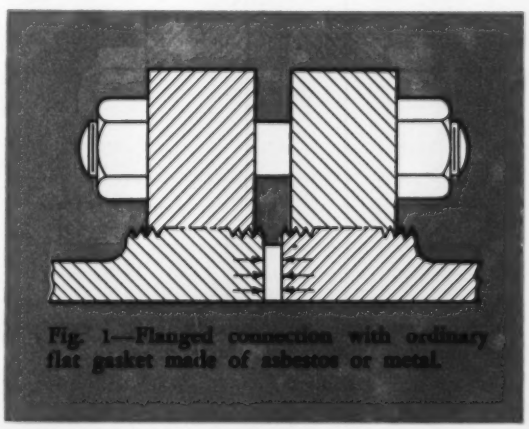


Fig. 1—Flanged connection with ordinary flat gasket made of asbestos or metal.

For purposes of this discussion, lower pressure groups may be defined. The high-pressure range is from 100 to 1,000 psi; the very high-pressure range, from 1,000 to 5,000 psi; and the quite high-pressure range, from 5,000 to 10,000 psi. While these ranges have presented certain special design problems, all of them have been solved by present day methods. The ultrahigh-pressure range, over 10,000 psi, presents its own peculiar problems.

Through most of the pressures to the vicinity of 10,000 psi, ordinary gasketing concepts apply. The usual method of sealing a joint specifies that the gasket material must not yield beyond stated, controlled limits. That is to say, the gasket surface will yield upon initial bolt loading. But after a certain load is reached, the gasket surface no longer yields, absorbing all added loading with-

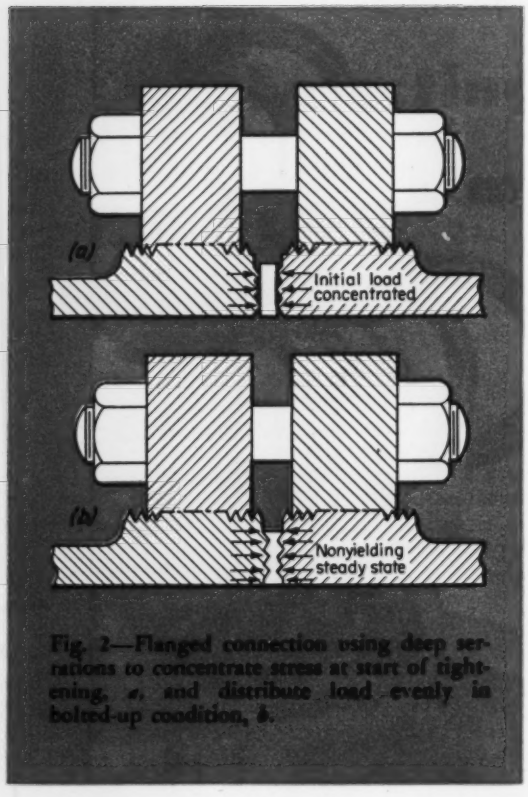


Fig. 2—Flanged connection using deep serrations to concentrate stress at start of tightening, *a*, and distribute load evenly in bolted-up condition, *b*.

out being crushed. The gasket body itself never yields.

As design pressures increase, gasket materials of higher and higher yield strengths must be used to conform with the higher applied loads. However, the flange face on which the gasket seats must be harder than the gasket. Gaskets can be replaced, but replacement or refinishing of flanges may be difficult, or impossible. For this reason, the designer must make certain that the gasket does not deface or deform the flange face. If, as in the quite high-pressure range, it is necessary to use an extremely hard gasket to control yield, the limit in flange face hardness is approached. For example, if a hard stainless steel gasket is used, it becomes rather difficult to employ a flange that is harder than the gasket.

Flange dimensions are dictated by two different applied loads. The first, of course, is the load applied by the flange bolting to resist internal pressure. But added to this is the load applied by the bolting to press the gasket hard enough to seal the joint. In a large number of cases, flange dimensions are determined more by gasket requirements than by the internal pressure. As it becomes necessary to raise gasket yield stress, to insure that the gasket does not yield beyond prescribed limits, increased flange loads are needed to compress these gaskets at the same time to provide sealing. This leads to flange dimensions, in the ultrahigh-pressure range, of 9⅛ in. outside diameter by 4½ in. thick, with eight bolts, each 1½ in. in diameter. The pipe inside diameter available for fluid flow in such a case might be only 1 in., giving a ratio of over 9 to 1 between the outside diameter of the flange and the inside diameter of the pipe.

The premise that a gasket must not be allowed to yield fully retarded the design of really high-pressure connections until recently. The "nonyie'ded" gasket is easily adaptable to high and very high pressure, and with some tricks of the trade it can be used into the quite high-pressure range. But the nonyielded gasket does not stand up to the requirements of ultrahigh pressure.

Basic Gasket Designs: Study of a few basic gasket designs will show how the nonyielding concept has been employed. First, there is the usual flat gasket. No part of this gasket yields. True, there is some flattening of surface imperfections, but one cannot point to any one area and say that this part will yield. Fig. 1 shows the general shape of such a connection, and the distribution of load over the total gasket surface.

Various methods have been used to cause temporary stress concentration on a gasket, to produce a short-term surface yield and deve'op a perfect seal. After the initial flow of the gasket material, contact area is greatly increased, so that no further yielding can occur.

A type of gasket design that uses an elementary method of causing stress concentration is shown in Fig. 2*a*. Notches or deep serrations are machined in the flange surface. Under initial applied bolt load, the grooves bite into the gasket, causing yielding. When the grooves are fully imbedded, contact is made over the full gasket face,

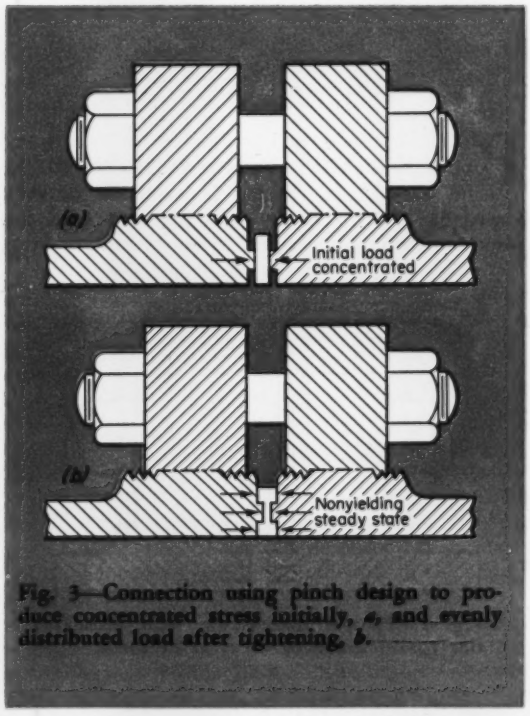


Fig. 3—Connection using pinch design to produce concentrated stress initially, *a*, and evenly distributed load after tightening, *b*.

and no further yielding can occur, as shown in Fig. 2*b*.

The gasket, f'ange, and bolting must be so designed that, when full contact is secured, all yielding will stop. Fig. 3 shows a similar method of ensuring short-term localized stress concentration.

Another method of obtaining stress concentration is by the intersection of slightly different planes. A lens-ring arrangement illustrating this method is shown in Fig. 4*a*.

Radius of the ring surface is made slightly different than the radius of the flange gasket surface. This causes a 'ine of high stress concentration when bolting of the connection is started. Then, as more bolt loading is applied, the contact area is increased, and in the process the gasket surfaces are crushed to obtain the seal. The condition is eventually reached where gasket resistance equals applied bolt load, and no further yielding occurs, as shown in Fig. 4*b*.

Other gasket shapes, such as the wave ring and the "delta," shown in Fig. 5, go through the same steps—initial yielding, increase of gasket bearing surface, and finally a nonyielding steady state. Some of these gasket shapes utilize interna! pressure to aid in pressing the gasket into its seat.

The purpose of all these shapes is to provide focal points for localized stress, to cause yielding and crushing at those points. A perfect seal is obtained since the metal is made to flow. However, the connection is designed so that in the bolted-up state all yielding will be completed, and the nonyielding condition will be reached.

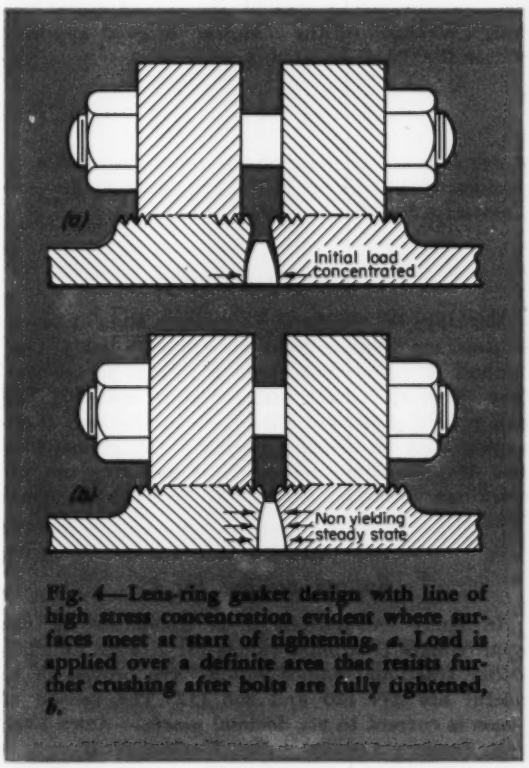


Fig. 4—Lens-ring gasket design with line of high stress concentration evident where surfaces meet at start of tightening, *a*. Load is applied over a definite area that resists further crushing after bolts are fully tightened, *b*.

Ultrahigh-Pressure Designs: The pressure barrier was breached when it was realized that with loads in the ultrahigh-pressure range, any available gasket material would be stressed well beyond its yield point. So why not design with this fact in mind? This point—designing around a gasket that is permitted to yield—was the Open

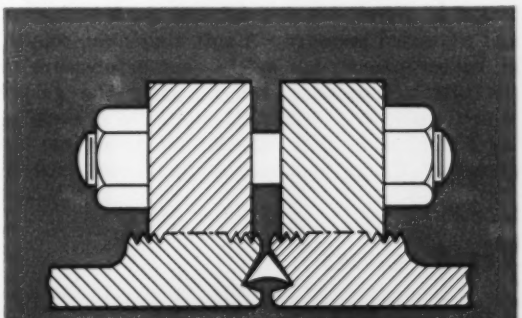


Fig. 5—"Delta" shape, typical of other gaskets which go through the steps of initial yielding, increase of gasket bearing surface, and finally a nonyielding steady state.

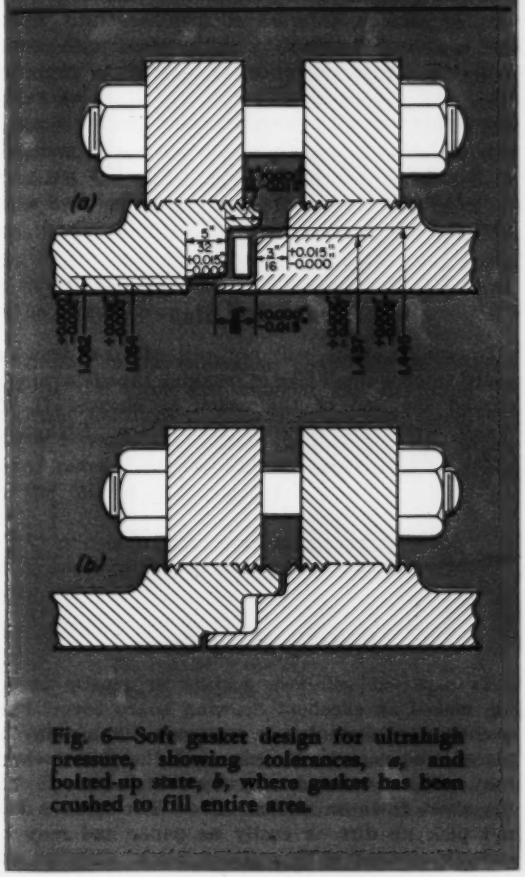


Fig. 6—Soft gasket design for ultrahigh pressure, showing tolerances, *a*, and bolted-up state, *b*, where gasket has been crushed to fill entire area.

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Sesame in ultrahigh-pressure development. This is the soft gasket idea that radically changed flange requirements. Such a flange, equivalent to the nonyielded gasket mentioned earlier, would be only 6⅜ in. outside diameter, 1 15/16 in. thick, with eight bolts only ¾ in. diameter. Every dimension—outside diameter, thickness and bolt diameter—has been decreased.

Of course, this soft gasket must be fully confined. Radial dimensions must be held to plus or minus 0.002-in., as shown in Fig. 6*a*.

With the gasket seat totally enclosed, there no longer is any relationship between gasket material and contained pressure. A soft aluminum, copper, or rubber gasket can safely contain pressure in the ultrahigh-pressure range. Here the gasket is performing its primary function, that of furnishing a fluid seal. It is not also adding a large unnecessary flange loading. A flange designed to hold the longitudinal internal pressure will definitely compress the gasket. Fig. 6*b* shows the general arrangement of such a flange. Added load required to compress the gasket is so nominal as to be insignificant.

What exactly happens when this flange is bolted up? First, the gasket is crushed, completely filling the confining space. Sealing is secured as all of the gasket material flows. Then, when the confining area is completely filled, the gasket can no longer be compressed, resulting in the counterbalanced forces necessary for a connection that will remain tight under field conditions.

This type of gasket design, a design wherein the gasket does its job of containing the fluid, and the bolting does its job of resisting the pressure, will allow further development in the ultrahigh-pressure range, beyond limits established by previous gasketing methods.

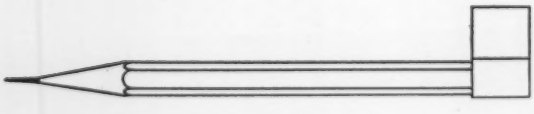
Tips and Techniques

Fahrenheit-Centigrade Conversion

This method for converting temperature differs from the conventional method in that the steps are the same regardless of whether the conversion is from fahrenheit to centigrade or vice versa, with the single exception of having to properly apply the proportionality factor. It is an exact conversion, not an approximation. The three steps are: (1) add 40 to the temperature, (2) multiply by 5/9 (F to C) or 9/5 (C to F), (3) subtract 40.—JAMES J. LAHN, *Westinghouse Electric Corp., Sharon, Pa.*

Pencil Roll Stop

Drawing pencils will not roll off the drawing board when a small flag of masking tape is wrapped around the end of the pencil as shown.—B. H. WAAG, *Grumman Aircraft Eng. Corp., Bethpage, L. I., N. Y.*



Drafting Board Cover

Transparent cellulose acetate or plastic sheeting makes an excellent drawing board cover. Frequently used formulas or conversion tables may be placed underneath the edges of the sheet where they will not be hidden by drawings before taping the sheet down on all four sides. The surface does not pick up dirt as easily as paper and may be quickly cleaned with a damp cloth. Another advantage is that compass center holes in the sheet do not enlarge as they would in a paper cover.—H. H. LAWRENCE, *Hatfield, Mass.*

Strength of a Screw in Tension

Allowable tension load on a bolt or screw is equal to the stress area at the thread times the design strength of the material. A good approximation for the stress area, A, is

$$A = \frac{11}{14} D \left(D - \frac{2}{n} \right)$$

where D = major diam of the thread, in.; and n = number of threads per in.—ARNE BENSON, *Sanders Associates Inc., Nashua, N. H.*

Preserving Markings

Markings on templates to indicate sizes of holes, ellipses, etc. usually wear off rather quickly. One method of preserving these markings is to coat them with clear nail polish. Before applying the nail polish, it is advisable to clean the area thoroughly with an eraser to remove any grease film and, if necessary, use india ink to bring out all markings.—GEO. T. MCCOPPIN, *Technidraft, Newark, O.*

Approximations for Pi

In many calculations it is convenient to use approximate fractional values for π, such as 22/7. Other fractional values which have proved to be useful are 377/120 and 355/113. The second of these is correct to six decimal places.—ARNE BENSON, *Sanders Associates Inc., Nashua, N. H.*

Stresses and Deflections in

Tapered Cantilever Beams

By Durward Cason
Georgia Institute of Technology
Atlanta, Ga.

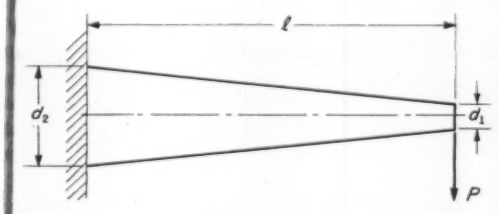


Fig. 1—Typical tapered beam. Thickness is constant in direction normal to page.

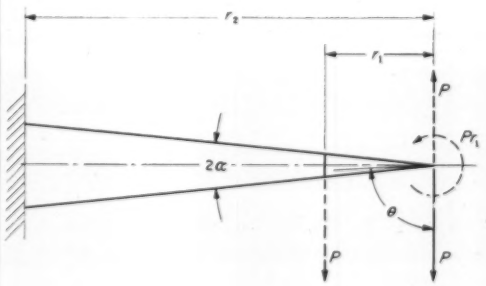


Fig. 2—Equivalent beam corresponding to Fig. 1.

Nomenclature

E = Modulus of elasticity, psi
u = Displacement in radial direction, in.
v = Displacement in tangential direction, in.
$\gamma_{r\theta}$ = Shearing strain, in. per in.
ε_r = Strain in radial direction, in. per in.
ε_θ = Strain in tangential direction, in. per in.
ν = Poisson's ratio (0.30 for steel)
σ_r = Normal stress directed toward apex, psi
σ_θ = Normal stress directed in tangential direction, psi
$\tau_{r\theta}$ = Shearing stress, psi

STRESSES and deflections in cantilever beams with moderate taper can be found approximately from elementary beam theory. For large taper values, however, such results may be considerably in error, indicating the need for more accurate methods of solution. In this article, the method of elasticity is used to determine deflections of beams with varying amounts of taper, and results are plotted in the form of working charts. Comparison of the results of the elementary and the more exact theories is also shown.

Taper of the beam sketched in Fig. 1 is in the direction of the load; thickness is constant in the direction normal to the load. To determine deflections and stresses, an equivalent beam, Fig. 2, is substituted for the actual beam. With the assumption of the load P at the apex and the couple Pr_1 as shown, the beam in Fig. 2 is statically equivalent to the original case.

Stresses in the equivalent beam due to application of the force and moment can be found by methods detailed in Timoshenko and Goodier*, where stresses are defined in terms of the polar co-ordinates r and θ. Stress distribution is given by the following equations:

$$\sigma_r = -\frac{P\cos\theta}{\left(\alpha - \frac{\sin 2\alpha}{2}\right) r} + \frac{2\,Pr_1 \sin 2\theta}{(\sin 2\alpha - 2\alpha\cos 2\alpha)\, r^2}$$

$$\sigma_\theta = 0$$

$$\tau_{r\theta} = -\frac{Pr_1\,(\cos 2\theta + \cos 2\alpha)}{(\sin 2\alpha - 2\alpha\cos 2\alpha)\, r^2}$$

Normal and shearing stress distributions are calculated from these equations and plotted in Figs. 3 and 4 for the particular case where $r_1/r_2 = 0.20$ and $\alpha = 0.20$. It is seen that the normal

*S. Timoshenko and J. N. Goodier—*Theory of Elasticity*, McGraw-Hill Book Co. Inc., New York, 1951, Page 96.

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stress distribution is close to the linear distribution predicted by the elementary beam theory. Shearing stress is also seen to approach the parabolic distribution. However, for larger angles of taper, stress distribution is known to be quite different from that predicted by the elementary theory.

Deflection equations, expressed in terms of the polar co-ordinates, and calculated on the basis of the known stress distribution are:

$$\varepsilon_r = \frac{\partial u}{\partial r} \qquad \varepsilon_\theta = \frac{\partial v}{r\partial\theta} + \frac{u}{r}$$

$$\gamma_{r\theta} = \frac{\partial u}{r\partial\theta} + \frac{\partial v}{\partial r} - \frac{v}{r}$$

or, in terms of unit stresses,

$$\varepsilon_r = \frac{1}{E}(\sigma_r - \nu\sigma_\theta) \qquad \varepsilon_\theta = \frac{1}{E}(\sigma_\theta - \nu\sigma_r)$$

$$\gamma_{r\theta} = \frac{1}{G}\tau_{r\theta}$$

Combining these equations, integrating, and solving for the coefficients, equations for the displacements, u and v, along the center of the beam ($\theta = \pi/2$) are:

$$u = 0$$

$$v = \frac{P}{E\left(\alpha - \frac{1}{2}\sin 2\alpha\right)}\left[1 + \log_e\left(\frac{r_1}{r_2}\right) - \frac{r_1}{r_2}\right] +$$

$$\frac{P}{E(\sin 2\alpha - 2\alpha\cos 2\alpha)}\left\{\left[(1-\nu) - 2(1-\nu)\frac{r_1}{r_2} + (1-\nu)\left(\frac{r_1}{r_2}\right)^2\right] + \cos 2\alpha\left[(1+\nu) - 2(1+\nu)\frac{r_1}{r_2} + (1+\nu)\left(\frac{r_1}{r_2}\right)^2\right]\right\}$$

For small angles of taper and $\nu = 0.30$, the deflection equation reduces to

$$v = \frac{P}{E\left(\alpha - \frac{1}{2}\sin 2\alpha\right)}\left[1 + \log_e\left(\frac{r_1}{r_2}\right) - \frac{r_1}{r_2}\right] + \frac{2P}{E(\sin 2\alpha - 2\alpha\cos 2\alpha)}\left[1 - \frac{2r_1}{r_2} + \left(\frac{r_1}{r_2}\right)^2\right]$$

Deflections are calculated from these equations and plotted for various values of r_1/r_2 and angles of taper α in Fig. 5. In order to use the graph, values of d_1, d_2, and l (Fig. 1) are converted to r_1/r_2 and α as follows:

$$\frac{r_1}{r_2} = \frac{d_1}{d_2} \qquad \alpha = \frac{1}{57.3}\tan^{-1}\frac{d_2 - d_1}{2l}$$

Deflections may then be read from Fig. 5.

Results of the exact method can be compared with those of the elementary beam theory. The method of moment area provides the basis of this comparison:

$$v = \int_0^l \frac{Mx\,dx}{EI}$$

In this equation, x is taken from the free end, and the moment of inertia I varies along the length because of the taper. Performing the integration:

$$v = \frac{3P}{2E\tan^3\alpha}\left[\log_e\left(\frac{r_2}{r_1}\right) + \frac{2r_1}{r_2} - \frac{1}{2}\left(\frac{r_1}{r_2}\right)^2 - \frac{3}{2}\right]$$

For small angles of taper, this equation gives results very close to those of the more exact solution shown previously and is sufficiently accurate for many design problems. As the angle of taper increases, however, errors in the solution increase. In Fig. 6 comparison is made between the two solutions for constant value of $r_1/r_2 = 0.20$ and varying values of α. This graph can be used as a check on the accuracy of the elementary solution in a particular design problem. If the need arises, the more accurate results obtained by the method of elasticity may be used.

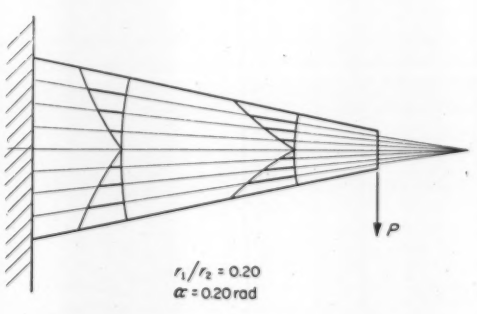


Fig. 3—Normal stress distribution in tapered beam as calculated by method of elasticity.

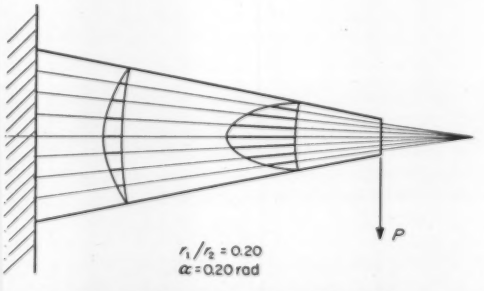


Fig. 4—Shearing stress distribution in tapered beam as calculated by method of elasticity.

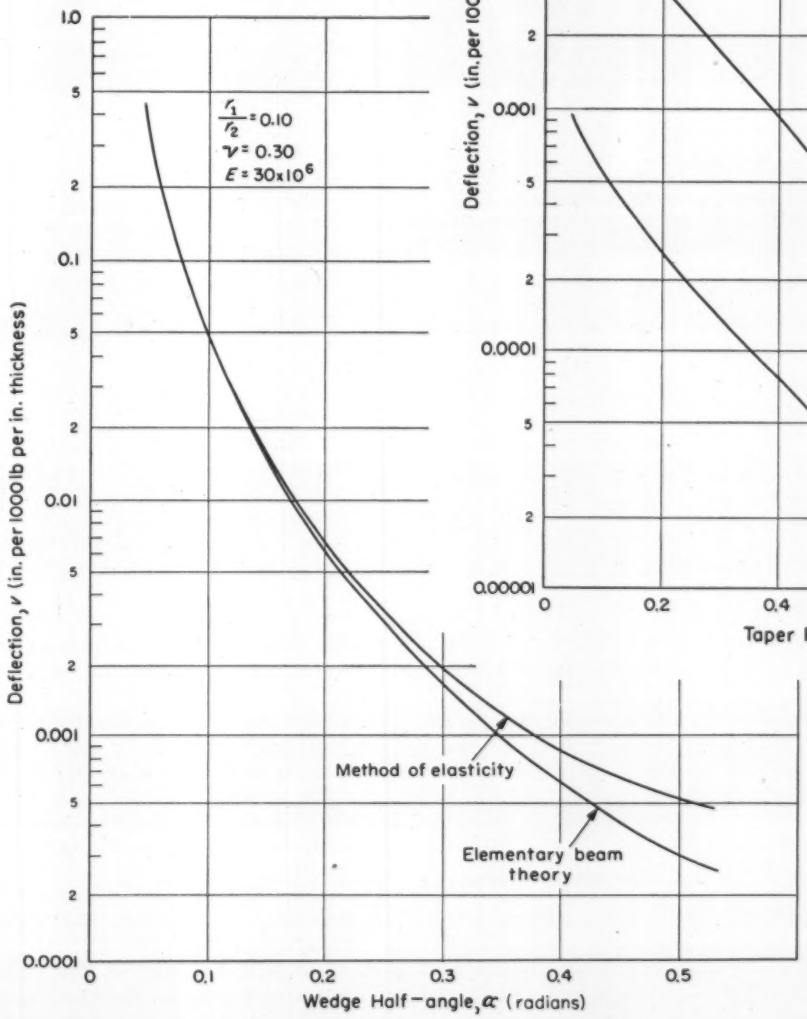

$\frac{r_1}{r_2}$ = 0.10
ν = 0.30
E = 30x10^6
Deflection, v (in. per 1000 lb per in. thickness)
Method of elasticity
Elementary beam theory
Wedge Half-angle, α (radians)

Fig. 5 — Right — Tapered beam deflection as a function of taper ratio and cone half-angle.

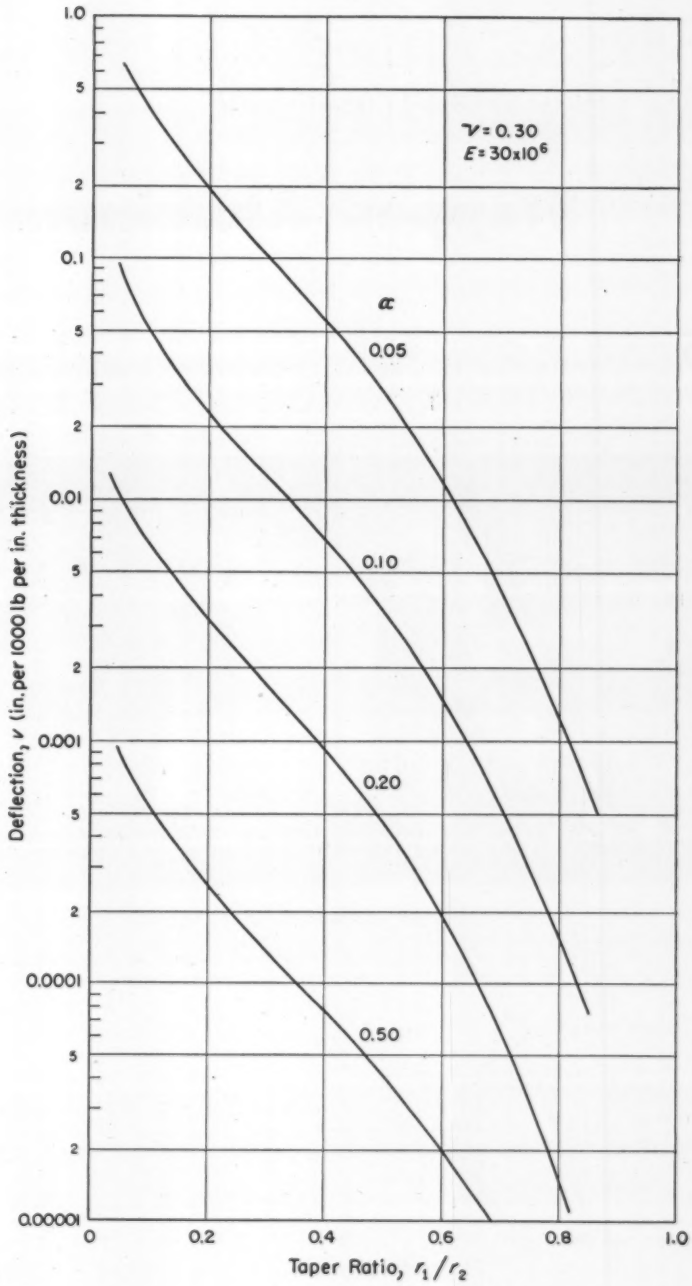


Fig. 6 — Left—Comparison of tapered-beam deflections as calculated by elementary beam theory and method of elasticity.

XUM

Design considerations for

Stepped Aluminum Extrusions

STEPPED extrusions are commonly produced at the present time utilizing two sets of extrusion dies, Fig. 1. The small or minor section is extruded first to the desired length, at which point the extrusion cycle is interrupted long enough to change dies to produce the major configuration. In most cases the dies are comprised of two segments to facilitate removal of the dies from the extruded part. Fig. 2 represents a schematic tooling arrangement and operational sequence for this method of producing stepped extrusions. A modification of this process is allowed through improved press designs utilizing a secondary locking arrangement to hold the minor section dies in position, Fig. 3. If single-piece dies are used, the minor must be stripped off the end of the extruded section with the major die being threaded over the end of the minor part.

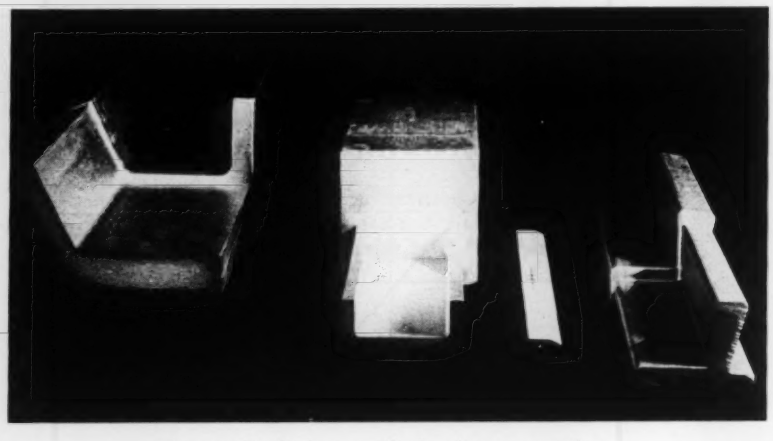


Fig. 1—Typical stepped aluminum extrusions.

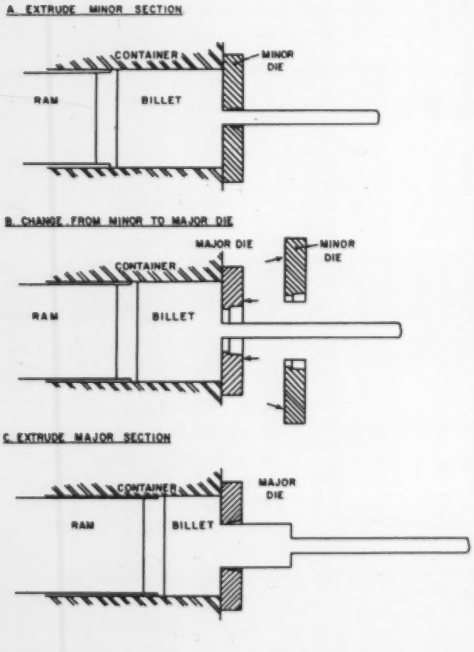


Fig. 2—Step extrusion process using two sets of extrusion dies.

Dimensional Tolerances: In working from the finished machined part to the stepped extrusion requirements, dimensional tolerances are of prime importance to insure ability to manufacture the desired part yet avoid an excess of stock. Stepped extrusion tolerances have not been standardized throughout the industry at present; however, tolerances illustrated here are typical of those that can be obtained today. These differ primarily from normal extrusion tolerances in straightness and step area dimensions. The straightness of the overall part is measured by deviation from a reference line, with the junction area (8 in. on either side of the step) being excluded, Fig. 4.

The straightness of minor and major positions of the extrusion is determined individually with the junction area excluded. The minor and major positions are usually furnished to standard extrusion straightness tolerances.

Due to the change of flow conditions in extruding the major and minor sections, the junction area

DESIGN ABSTRACTS

By C. J. Huffman

Kaiser Aluminum & Chemical Corp.
Oakland, Calif.

usually presents the greatest straightening problems. Typical junction area tolerances and their application are shown in Fig. 5.

In the design of stepped extrusions produced from split dies, parting line locations should be considered not only from the tolerance standpoint but from the ability to remove tools from the section. In some cases it may be necessary to provide slight draft angles on extended elements to accomplish this. While the major and minor sections may frequently have a common plane, this is not a requirement of the process. In all cases the major section must completely enclose the minor.

Cross-sectional tolerances of stepped extrusions are usually greater than usual due to the inherent instability of split dies. It is generally necessary to provide sufficient machining stock on all surfaces of the section to be able to obtain the required accuracy of dimension and surface finish requirements. This is particularly true regarding dimensions which fall across the parting lines of the die. An additional tolerance is usually required on these dimensions due to the possible shifting of the die segments, Fig. 6.

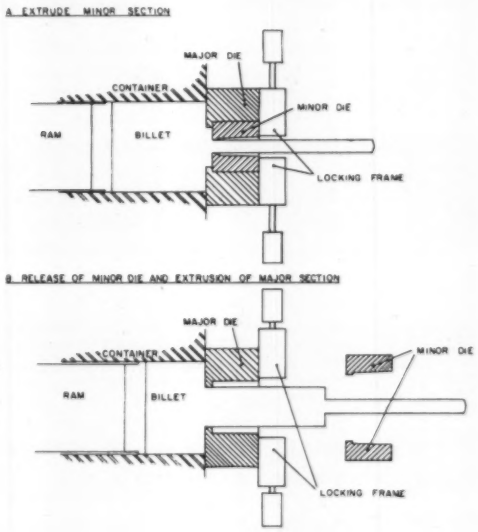


Fig. 3—Step extrusion process using secondary locking frame.

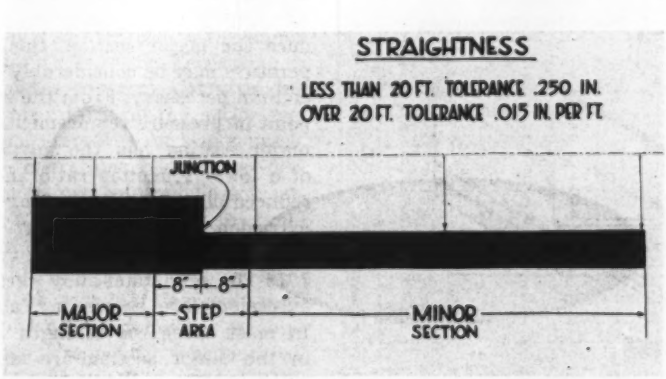


Fig. 4—Overall dimensional tolerances for stepped extrusions.

Effects of Section Change: With the abrupt change in flow pattern between the minor and major sections, areas of reduced mechanical properties are sometimes encountered at the junction extremities of the major section. So-called dead-metal areas not included in the direct flow path are removed by following recommended machining practices shown in Fig. 7.

An additional consideration which must be recognized is the cross-sectional areas of major and minor sections and the ratio of major area to minor area. These will have a marked influence on the mechanical properties obtainable. In normal aluminum extrusions, mechanical properties depend on the degree of working the cast ingot received as measured by the reduction ratio. The reduction ratio is the ratio of extrusion press container area to the area of the part being extruded. Substandard mechanical properties are obtained in 7075 aluminum alloy when reduction ratios less than about 6:1 are used. Reduction ratios greater than about 30:1 for 7075 alloy require excessive pressures.

Table 1—Mechanical Properties of Typical 7075-T6 Aluminum Alloy Step Extrusions

Extrusion	Major Part					Junction			Minor Part				
	Thickness (in.)	Area (sq in.)	Tensile Stress (1000 psi) Ult.	Yield	Elongation (per cent)	Tensile Stress (1000 psi) Ult.	Yield	Elongation (per cent)	Thickness (in.)	Area (sq in.)	Tensile Stress (1000 psi) Ult.	Yield	Elongation (per cent)
A	1.70	8.69	89.4	83.2	8.8	89.9	81.6	9.0	0.68	4.42	90.3	84.2	9.1
B	3.06	16.05	89.4	82.1	8.0	...	...	..	0.72	5.98	90.2	84.8	10.0
C	2.23	17.29	86.7	81.9	8.9	87.3	80.3	6.8	1.10	5.36	87.0	79.9	10.1
D	1.98	21.28	88.8 80.1*	81.2 71.7*	10.2 6.8*	88.0	78.8	9.5	1.58	12.11	91.6 84.7*	83.4 72.5*	9.2 9.8*
E	4.66	28.95	86.8 71.2*	81.2 60.8*	11.0 4.6*	...	...	..	1.40	10.63	91.0	84.4	9.0
F	5.32	29.32	88.2 71.0*	75.8 58.8*	9.5 4.7*	79.5	71.9	4.0	0.485	3.30	90.4 77.6*	84.3 72.4*	12.0 4.0*
	Minimum Specification Values												
	0-0.249	All	78.0	70.0	7.0								
	0.250-2.999	All	80.0	72.0	7.0								
	3.000-4.499	0-20	80.0	70.0	7.0								
	3.000-4.499	Over 20 thru 32	78.0	70.0	6.0								
	4.500-5.000	0-32	78.0	68.0	6.0								

*Data for transverse direction of testing.

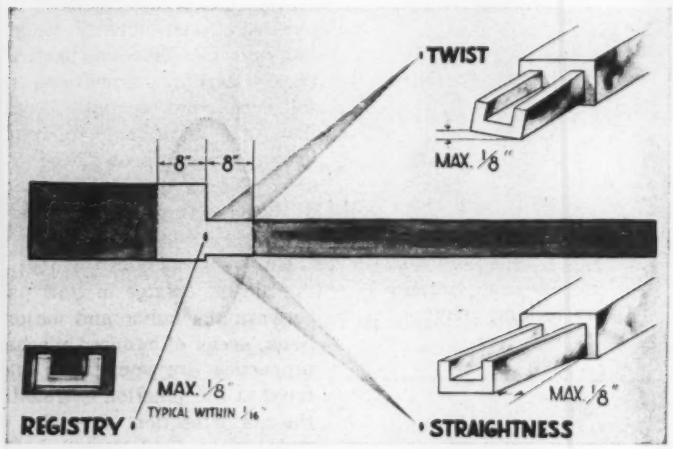


Fig. 5—Typical junction area tolerances and their application.

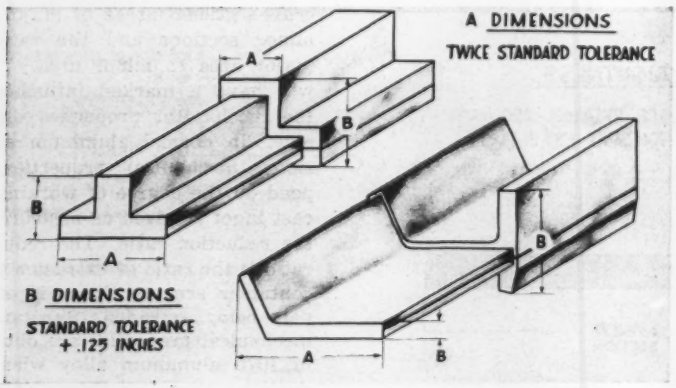


Fig. 6—Cross-sectional tolerances for stepped extrusions, showing extra tolerances across parting lines.

The designer usually has no knowledge or control of the container size on which a part is to be produced. To make the section producible under optimum conditions, the major area to minor area ratio should not exceed 5:1.

Mechanical Properties: In some cases, due to the differences in areas and thicknesses, it will be necessary to work to two sets of allowable design stresses in the major and minor parts of the extrusion. As the producer cannot vary extrusion temperatures rapidly enough to create ideal conditions for both major and minor sections, a compromise must be used for the extrusion of both parts.

For example, it may be necessary to use an elevated extrusion temperature to start the minor section moving through the die. After the dies are changed to produce the major section, this temperature may be considerably higher than necessary. From the standpoint of pressure requirements, the major section has the advantage of a lower reduction ratio and the reduced billet length resulting from extrusion of the minor part.

Mechanical properties for typical 7075-T6 aluminum-alloy stepped extrusions are shown in Table 1. In most cases the strength levels in the minor section are slightly greater than in the major, with the junction properties being equal to or slightly lower than in the major section. The effect of higher

than recommended major to minor area ratios will be noted in Extrusion F where the ratio is 8.9:1. In this case the strength levels in the major section are considerably below those of the minor section in both longitudinal and transverse directions, with the junction properties falling below those of the major section.

Investigations have been made to determine mechanical property levels along a specific line from front to back of the extrusion. Results of a typical study are shown in Fig. 8. Mechanical properties are fairly uniform along the length of the part following the general trend indicated above. The lowest mechanical properties are above the specification minima.

Finishing Operations: Finishing operations for step extrusions follow, in general, the practices used for other aluminum products. A typical sequence of operations for 7075 aluminum alloy step extrusions would be:

1. Extrude
2. Solution heat treat
3. Stretch straighten
4. Cut to length
5. Age

In the solution heat-treating operations, time at temperature would be determined by the thickest element of the major section which would probably be slightly longer than the time required for the minor section alone. The normal practice in stretching is to grip each end of the section in a hydraulic unit and exert the necessary stretching force to straighten the part. Due to the differences in area, all of the permanent set in stretching is obtained in the minor section. It may be necessary in some cases to carry out straightening operations on the major section and step area on a gag press. These operations would be performed before solution heat treatment wherever possible to avoid leaving residual stresses.

As all step extrusions are machined to varying degrees, problems of warpage following machining are frequently encountered. This is very likely aggravated by differential residual stress patterns in the minor and major sections of the extrusion. Experience on plate has indicated that a 2 per cent permanent-set stretch will virtually eliminate warpage which occurs following machining operations. Experience on extrusions indicates similar results may be achieved by stretching.

New Developments: It has long been considered a possibility to produce parts with two, three or more steps. In these cases, rather than two sets of dies, three or more sets would be used to produce the desired configurations. This, of course, would introduce additional operations in producing a given part with increased tooling costs which would add to the price of the section. In most cases it has appeared difficult to economically justify additional steps.

In other areas of development of extruded products for aircraft usage, integrally stiffened panels are now becoming commonplace. These products are presently avail-

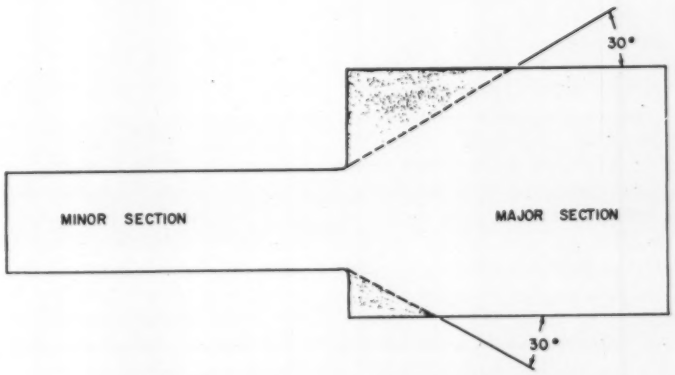


Fig. 7—Recommended machining practice for removing dead-metal areas. Shaded portion is removed.

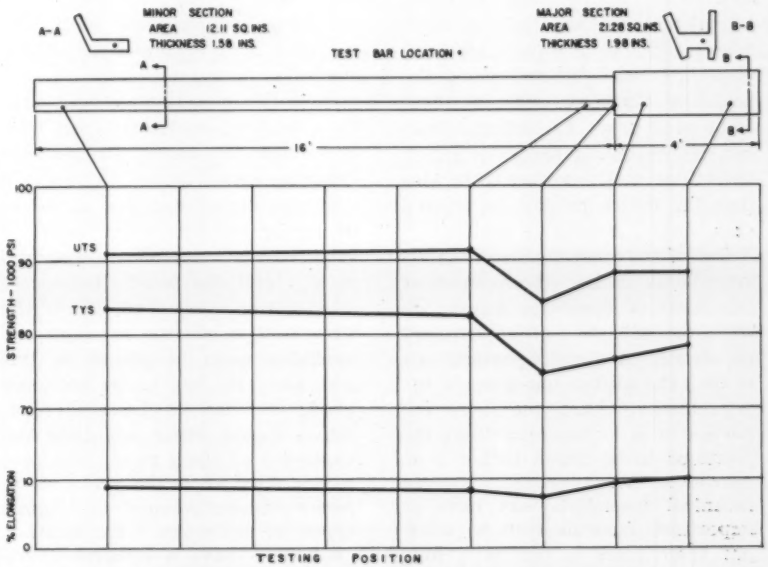


Fig. 8—Effect of testing position on mechanical properties of a typical 7075-T6 step extrusion.

able in widths up to 25 in. extruded in a flat configuration. Development work indicates greater widths are available from existing equipment. Frequently this type of section will be extruded in a V or tubular configuration to obtain greater widths.

The extrusion of tubular parts with external or internal rifling has been carried on for some time. These techniques have been developed to a point where it is possible to maintain very close tolerances on the degree of spiral. Parts such as these have found application in the missile field.

From a paper entitled "Stepped Aluminum Extrusions — Present and Future" presented at the SAE Aircraft Production Forum in Los Angeles, October, 1956.

Selecting personnel for effective

Systems Engineering

By Dean E. Wooldridge

Ramo-Wooldridge Corp.
Los Angeles

SYSTEMS engineering connotes a basic method of approach that must be taken if effective work is to be done in large cooperative scientific development projects. Such large-scale technical projects have in recent years come to characterize the development of new military weapons and are beginning to appear in connection with the development of modern systems for increasing the efficiency and productivity of business and industry.

A systems project must (1) involve concurrent development work in a number of technical fields, (2) require major state-of-the-art advances in several of these fields, and (3) involve such intimate interrelationships among the decisions made in each of these fields as to prevent a lasting, clear-cut delineation of separate design objectives, and therefore to require that the entire project be treated as a single, indivisible entity.

One of the most important single ingredients in the effectiveness of this kind of operation has to do with the selection of supervisory personnel. A very important rule is that the higher one goes in the organization chart, the more important it is for the men filling the positions to be broad rather than narrow in their approach. Narrow technical specialists may have an important place in systems work, but their place is not at a high supervisory level.

In a guided missile project, for example, the man who heads the guidance activities for the entire project must also be a pretty good aerodynamics, structures, and propulsion man, whereas the aerodynamics head must in turn comprehend enough of the guidance problem that when these people get together they can speak a common language and understand one another's mutual problems to the extent that proper choices can be made among the many technical alternatives that come up.

It goes without saying, of course, that the head of a major technical area must first of all be an unusually competent scientist or engineer. No mistake is more fatal, and yet more common, than assuming that, because a narrow technical specialist is not suitable for supervisory responsibility, the boss of the operation should therefore be a nontechnical man who has, however, been trained in "management."

In the highly complex activities of major systems work, what is required is "technical management," and the word "technical" must not be overlooked. One of the very best scientists or engineers available must be placed in this position. He has to be not only good; he has to have a reputation among other scientists and engineers of being good. His past record must show ten years of superior accomplishment in original types of activities. In addition, he has to have a breadth of interest, not only in technical areas, but must be somebody who does not think that the only purpose of an accountant is to hamstring the engineers. He has to realize that accountants have problems, too.

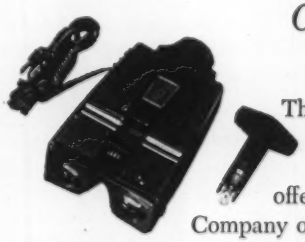
It is a good thing that many of the beliefs of the man in the street are not true, especially the one that scientists and engineers are temperamentally and constitutionally incapable of broad, educated, mature approaches to such problems; if so, this country would be in a very sad state, and certainly our military program would be years behind where it is today. Fortunately, there are people with scientific and engineering background who develop a broad approach to human relations, an understanding of what goes on in other nontechnical areas, and an ability to work well in these situations. There is only one solution to manning up one of the projects properly and that is to get such a man. It can't be done the easy way.

Of course, to avoid diluting the efforts of the senior technical men who control this kind of activity, competent, experienced administrative people must be assigned to assist them. More than this, all aspects of the organization and of its methods and procedures must be tailored as carefully as possible to maximize the effectiveness of the all-important scientists and engineers. These observations are of importance to administrative people who may be interested in making careers in technical systems organizations. There is indeed a great need and a good future for able administrative people in such organizations, but such work is of a service character to a greater extent than it is in many organizations.

From a paper entitled "Systems Engineering" presented at the Third Annual Conference for Engineers and Architects at Ohio State University, Columbus, Ohio, May, 1956.

Big News in Stereo Viewers

Chicago Molded uses phenolic of top dimensional stability



The new, prestige-building Realist Stereo Viewer at the left is now being offered by the David White Company of Milwaukee, Wisconsin.

It features: optional power for illumination – *either from a light socket or battery;* knob-easy brightness control; a new focusing adjuster; a thumb wheel interocular adjuster that permits each viewer to set the proper distance between eyes.

The viewer is making big news in plastics, too! The eleven parts you see above are all custom molded. For top dimensional stability so vital in precision optical equipment, Chicago Molded has used an improved, compression molded phenolic that is highly impact resistant. For sales appeal and quick product identification six parts are a sprightly green polystyrene. For production economy, all six have been injection molded at one time in a six-cavity mold.

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HELPFUL LITERATURE

for Design Executives

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Tubing

Charts and engineering data to aid in the selection of tubing as to size, wall thickness and material for various operating requirements are given in illustrated catalog file 4305. Factors considered are flow requirements, pressures, severity of service and temperatures. 8 pages. Parker Appliance Co., Tube & Hose Fittings Div.

Circle 401 on page 19

Retaining Rings

An increased range of sizes is available in the Industrial line of retaining rings described in illustrated catalog. Data are given on 24 sizes of open type retaining rings for 1/25 to 1-in. shafts, 37 sizes of internal rings for ¼ to 2 1/16-in. housings and 48 size of external rings for shafts from 1/8 to 2¼ in. 12 pages. Industrial Retaining Ring Co.

Circle 402 on page 19

Metered Lubrication

Distribution systems for all types of automatic lubricators are described in bulletin 4A. Following a system from oil reservoir to lubrication point, booklet relates how to obtain the best results from any such system. It also discusses their various components. 12 pages. Bijur Lubricating Corp.

Circle 403 on page 19

Butterfly Valves

Pressure drop and flow tables, conversion tables, theory and application and recommended materials are among data offered in butterfly valve manual B-2 to help engineers select the correct valve and determine space requirements. Rubber-seat butterfly valves from 4 in. diameter up, for handling liquids and gases, are covered. 40 pages. Henry Pratt Co.

Circle 404 on page 19

Automotive Transmission

Design and performance information on the new Transverter power train "package" for off-highway and stop-and-go service in automotive equipment is given in bulletin TV-100. Comprised of torque converter, disconnect clutch and transmission, drive is rated for engine torque up to 325 lb-ft. 8 pages. Clark Equipment Co., Transmission Div.

Circle 405 on page 19

Insulation Connectors

Alden handbook supplement features series of integral molded insulation connectors. These multiwire connectors provide strain relief on all leads, moisture seal, prevention of arc-over and corona suppression. Assembly consists of contact leads molded into a finished connector. 4 pages. Alden Products Co.

Circle 406 on page 19

Resistance Welding

Vol. 4, No. 7 of "Resistance Welding at Work" explains use of Sciaky resistance welding techniques to fabricate miter joint aluminum window frames. This method assures a water-tight joint. Two type BMW-1 200 kva flash-butt welders are used in this application. Sciaky Bros., Inc.

Circle 407 on page 19

External Cotters

Dimensional data and price information of 14 external cotters which are considered standard are presented in data sheet Sec. 16, P. 5. Pin dimensions for each cotter are also given. 2 pages. Hunter Spring Co.

Circle 408 on page 19

Circular Weldments

Various types of weldments and rings produced for specific requirements are covered by illustrated catalog. Flash welding principles and typical products are discussed. 8 pages. Dresser Mfg. Co., Special Products Dept.

Circle 409 on page 19

High Pressure Tubing

Supplied either as heavy single or as double wall tubing, super pressure tubing is designed for safe service at 100,000 psi. Ten sizes range from ⅛ to ¾-in. OD in increments of 1/16-in. It is described in Data Memorandum No. 22. 3 pages. Superior Tube Co.

Circle 410 on page 19

Automatic Clutches

Specifications of various capacities of automatic clutches and transmissions for use with equipment driven by gasoline engine or electric motor are presented in illustrated bulletin 56-D-1. Stock sizes range to 25 hp, and custom models can be provided for large drivers. 4 pages. Salsbury Corp.

Circle 411 on page 19

Aluminum Color Code

Illustrated chart gives actual color identification code for aluminum rod, bar and wire alloys as recommended by the Aluminum Association. Listed are 32 alloys and their respective color codes. It also depicts Kaiser Aluminum color coding for identification tags on wire alloys. 4 pages. Kaiser Aluminum & Chemical Corp.

Circle 412 on page 19

DC Power Supplies

Details of the new DC Solavolt are given in bulletin DC-245. This adjustable-output constant-voltage direct current power supply is offered with outputs ranging from 5-35 v to 250-400 v with amperages of 7 and 0.6-0.75 amp, respectively. 4 pages. Sola Electric Co.

Circle 413 on page 19

Metal Fasteners

The fifth revised edition of fully illustrated catalog on metal fasteners contains purchasing data on wide variety of bolts, nuts, screws, washers and miscellaneous fasteners. Standards, weights, design and other information have been included. Sterling Bolt Co.

Circle 414 on page 19

Thermal Conductivity Cell

The Gow-Mac model TR-11-B temperature regulated cell is designed for gas chromatography and other uses where work with high boiling gas components requires constant temperature of 200° C or higher. General description is given in data sheet TRC-9-56. 2 pages. Gow-Mac Instrument Co.

Circle 415 on page 19

Titanium Pipe & Tubing

Information provided in Technical Data Card 185 on seamless titanium metal pipe and tubing for pressure and mechanical uses covers sizes and tolerances, mechanical and physical

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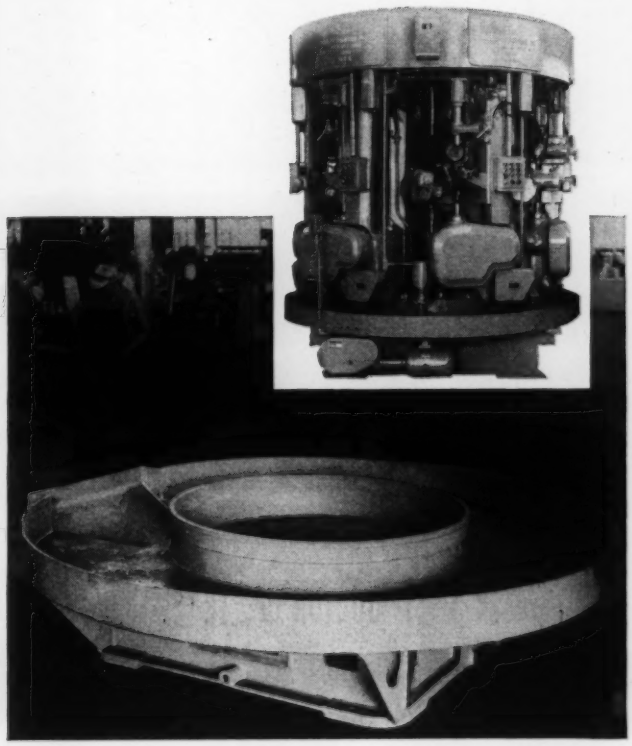
WHY use anything but welded steel

All welded base *for multiple spindle hobbing machine. Photos courtesy The Lees Bradner Company, Cleveland, O.*



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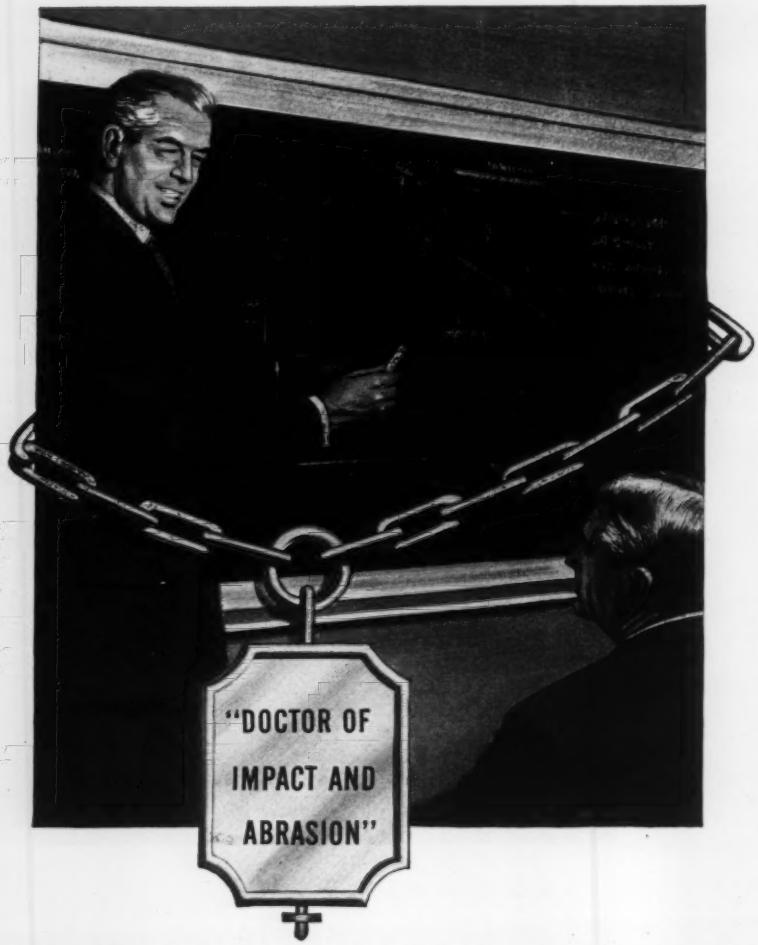

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Circle 563 on page 19

Helpful Literature

properties, corrosion resistance, fabrication and heat treatment. 12 pages. Babcock & Wilcox Co., Tubular Products Div.

Circle 416 on page 19

Magnetic Starters

How G-E magnetic starters can be modified to fit special conditions is shown in form GEA-6481. How-to-do-it pictures with each of the following type kits are provided: pushbutton and selector switch, auxiliary interlock, strongbox coil, third overload relay and fuse clip. 12 pages. General Electric Co.

Circle 417 on page 19

Overheat Detectors

Bulletin MC-134 on line of thermistor overheat detectors for aircraft service discusses their advantages, including stability and compactness and which permit leads up to 200 ft long and simple circuitry. Potential applications are depicted. 4 pages. Fenwal Inc.

Circle 418 on page 19

Mica Products

Technical information and applications of Supramica ceramoplastic and Mycalex glass-bonded mica products are contained in revised Engineering Data File. Products are suitable for use at up to 1000° F. File will be kept up-to-date with additional material. Mycalex Corp. of America.

Circle 419 on page 19

Forged & Rolled Rings

Seamless forged and rolled rings of Hi-Qua-Led leaded steel are subject of illustrated booklet SF-2. Included are test data and microstructures showing the even lead distribution and machining characteristics of the material. 8 pages. Alco Products, Inc.

Circle 420 on page 19

Hollow Aluminum Bars

Tolerances, mechanical properties and applications of hollow aluminum bar stock are discussed in brochure of this title. Tables list standard sizes of round and hexagonal stock, including wall thicknesses, dimensions and weight per foot. 8 pages. Harvey Aluminum.

Circle 421 on page 19

Rust Preventing Additive

Mixed with water, solvent or oil or used straight, Rust Veto M.P. is a water displacing rust preventive base which has a wide range of uses for indoor protection. Complete information, including physical properties and typical applications, are shown in

Helpful Literature

data sheet 2-459. E. F. Houghton & Co.

Circle 422 on page 19

Electronic Equipment

Four illustrated booklets give complete specifications, operating data and application information on direct current power supplies, five new galvanometers, galvanometer prices, and a four-channel 20-kc carrier amplifier. Consolidated Electrodynamics Corp.

Circle 423 on page 19

Servo Motors & Generators

Characteristics charts, performance data, dimensional drawings and specifications for the G-M line of servo motors and generators are contained in catalog No. 7. Information presented enables engineers to specify units and controls to fit specific needs. 16 pages. G-M Laboratories Inc.

Circle 424 on page 19

Pushbutton Switch

Details of the model 71PB Micro Switch are given on data sheet 111. This pushbutton switch for commercial equipment is rated 15 amp on 125/250 v ac with either normally open or normally closed design. 1 page. Minneapolis-Honeywell Regulator Co., Micro Switch Div.

Circle 425 on page 19

Hydraulic Gear Pump

The story of the development, production and performance of the Cessna gear pump is related in illustrated brochure "The Cessna Gear Pump." This high-efficiency pump is suitable for hydraulic power service at pressures in excess of 1000 psi. 6 pages. Cessna Aircraft Co., Industrial Hydraulics Div.

Circle 426 on page 19

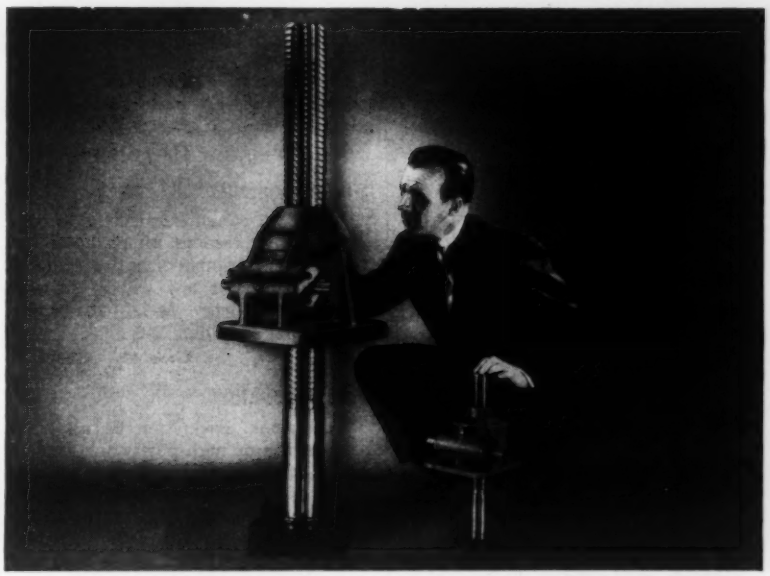
Variable Speed Drives

Illustrated folder 2574 describes P.I.V. variable speed drives which provide positive, accurate, infinitely variable speeds. Drives can be controlled by pneumatic, mechanical, electronic of hydraulic means to synchronize machine components or complete machines in automated setups. Design details are shown with cutaway views. 6 pages. Link-Belt Co.

Circle 427 on page 19

Electrical Contacts

Latest technical information in the fields of Thermometal, electrical contacts, composite metals and special alloys is inaugurated in the "Wilco Tech Bulletin." Published at irregular intervals, this publication will be sent



Here's A Device Every Machinery Designer Should Know About . . .

It's the Duff-Norton Worm Gear Jack, successfully used by many machine builders as a component of equipment for precise, positive control of linear motion, applying pressure, resisting impact. Two or more of these jacks can be connected by means of shafting and mitre gear boxes to give a positive drive, so that jacks always raise or lower under equal or unequal loads in perfect unison. Capacities range from 5 to 50 tons with any raise up to 25 inches; worm gear ratios, 6¾:1 to 27:1; turn of worm for each 1-inch raise, 10 to 40; available in either Acme or square threads. For protection against foreign matter certain models can be furnished with bellows boots.

Thousands of these jacks are in use today for table adjusting—machine adjusting—rolling mill adjusting—raising and lowering conveyors, machine beds, molds and dies, furnace lids, loading platforms, loading racks, gates, hinged mechanisms, arbor presses—adjusting electrodes—adjusting welding positioners.

Duff-Norton Worm Gear Jacks are available in 6 standard sizes. For complete specifications and detailed drawings, send for your free copy of a special brochure.

DUFF-NORTON Company

DUFF-NORTON COMPANY
Department MD
P.O. Box 1889, Pittsburgh 30, Pa.

Please send immediately a free copy of your new Worm Gear Jack Brochure.

NAME _____ TITLE _____

COMPANY _____ PHONE _____

ADDRESS _____

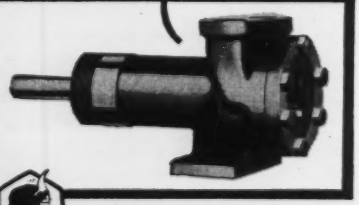
Circle 564 on page 19

VIKING supplies the Oomph

One little Viking Pump supplies the hydraulic power to raise this lift up to 38 feet. The stand can be raised, lowered or stopped at any level from the ground or stand, simply by starting or stopping the electric motor-driven pump.

Used in motion picture studios for lighting equipment and camera work, this lift is manufactured by Hamlin Hydraulic Lifts, Monrovia Machine Works, San Gabriel, California. They also make portable hydraulic lifts for factory maintenance crews, storage room stackers, scaffolding stands, light bulb changers, orchard sprayers, casket lifts, and many others. Hamlin has built these lifts for more than 20 years, and has included Viking Pumps as an integral part of each unit.

If you're looking for positive, dependable pumping, learn more about Vikings. Write for Bulletin 56Sh.



VIKING PUMP CO.

Cedar Falls, Iowa U.S.A.

In Canada it's "*ROTO-KING*" Pumps

See our catalog in Sweets

Circle 565 on page 19

Helpful Literature

free to designers and engineers concerned with these materials. 4 pages. H. A. Wilson Co.

Circle 428 on page 19

Boiler Controls

"The McDonnell Service Guide" discusses boiler feeders, piping hook-ups, testing and trouble shooting. Shown are feeders and low water cut-offs. Ask for bulletin M-71. 16 pages. McDonnell & Miller, Inc.

Circle 429 on page 19

Semiconductors

Full scale production of all sizes and shapes of high-purity metals and alloys in group 3 and 5 of the periodic chart, such as gallium, indium, aluminum, antimony and arsenic is announced in illustrated bulletin. Included are analyses and phase diagram charts. Alpha Metals, Inc.

Circle 430 on page 19

Socket Screws

"Why A Multiple-Spline Socket Screw," illustrated bulletin 723, explains this method of power transmission in a socket screw. Advantages and applications are described. Set and cap screw types are available down to No. 0 wire size. 6 pages. Bristol Co., Socket Screw Div.

Circle 431 on page 19

Potentiometer

Series 7700 Helipot precision potentiometer, subject of illustrated data sheet 54-26, is a ten-turn, metal-housed unit available with air-core or copper mandrel windings in wide range of total resistance. Specifications are given. 2 pages. Helipot Corp.

Circle 432 on page 19

Limit Switch

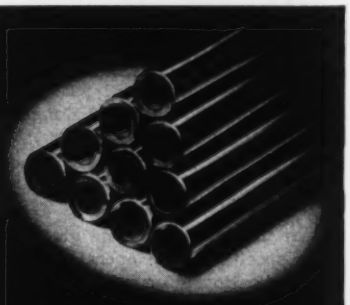
Design features and engineering data on series of rotating limit switches are found in illustrated bulletin 5605. They have heavy duty pilot ratings up to 480 v. Voltage rating charts, wiring illustrations, dimensional diagrams and other information are included. 4 pages. Furnas Electric Co.

Circle 433 on page 19

Nuts

How Fastex Speed Nuts save money by speeding assembly, decreasing weight and eliminating operations, among other ways, is described in illustrated catalog AF-2. Application data and specifications for wide variety of types are among contents. Illinois Tool Works, Fastex Div.

Circle 434 on page 19



LOOK NO FURTHER FOR QUALITY...

Bishop small diameter stainless steel tubing is not surpassed in meeting corrosion, heat, shock, stress and vibration.

It is not excelled in quality of starting stock... in accuracy of I.D. and O.D.... in dimensional precision... in finish.

When quality is of prime importance, for hydraulic lines, for aircraft parts, for instruments, for electronics... in fact wherever high quality steel tubing is indicated, look to Bishop for the finest... at comparable prices.

CAPILLARY, MECHANICAL, HYPODERMIC and AIRCRAFT Stainless Steel Tubing

... seamless and welded and drawn

(.008" to 1.000" O.D.)

(.003" to .083" Wall)

Nickel and Nickel Alloy Tubing

(up to .625" O.D.)

Catalog on Request

J. BISHOP & CO. PLATINUM WORKS

Stainless Steel Products Division

Malvern, Pennsylvania

Established 1842

Circle 566 on page 19

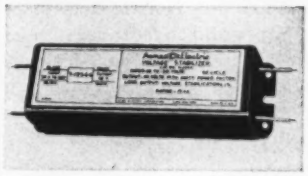
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Voltage Stabilizer

maintains voltage tolerance of ±1 per cent

Constant voltage stabilizer automatically provides ±1 per cent voltage tolerance by a parallel combination of fixed capacitance and magnetic core inductance to provide variable capacitive current. Stabilization is further improved with compensating winding to balance output circuit. Circuit is designed to provide electrical isolation between input and output



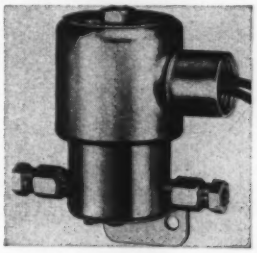
circuits. Units cannot be damaged by overloading; as percentage of overload increases above rated value, output voltage decreases until overload increase results in zero output voltage. Units of 15, 25, and 50 va have output voltages of 6.3 or 115 v. Units of 100 to 500 va capacity have input of 95 to 130 v and output of 115 v. **Acme Electric Corp.**, Cuba, N. Y.

Circle 451 on page 19

Pneumatic Valve

electrically-operated unit is noiseless

Electrically-operated pneumatic valve has close tolerances for spring, armature, guide, and materials to prevent alternating current noises. Valve is recommended for noiseless control of air conditioning damper motors and similar household and industrial applications. When unit is energized, valve will pass full air at supply pressures (up to 25 psi). When



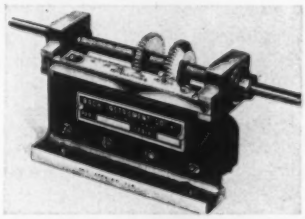
not energized, valve exhausts air from outlet port and closes inlet. Manual adjustment permits passing of air when not energized if desired. Coil is 60 cycle with voltage of 115, 208, 230, and 440. Port connections are ⅛-in. NPT. **Powers Regulator Co.**, 3434 Oakton St., Skokie, Ill.

Circle 452 on page 19

Limit Switch

offers adjustability of 1 part in 3400

Close-tolerance limit switch has rapid, precise adjustment to close operating tolerances and excellent repeatability in high or low speed



operation. Limitation of rotary motion is assured by two cams driven along a rotating lead-screw to actuate two precision snap-action switches. Lead screw is connected to system to be controlled by suitable gearing. Adjustability is 1 part in 3400 (0.03 per cent of full range), and repeatability is ±5 per cent of 360 deg revolution of lead screw. Travel of cams is from 1 to 70 turns of lead screw. Limits are quickly and accurately set to desired positions. Unit base size is 4⅛ in. by 1 11/16 in. Height is 2¾ in. and overall length is 6¾ in. **Arch Instrument Co. Inc.**, 101 Holmes St., North Quincy, Mass.

Circle 453 on page 19

Miniature Clinch Nut

is flush-mounting and self-locking

Self-locking miniature clinch nut combines flush-mounting and self-locking features. Unit is lightweight, effecting weight savings over conventional self-locking units of up to 87 per cent. Clinch nut resists temperatures up to 550 F and meets AN-N-10 full strength

requirements. **Kaynar Co.**, Kaylock Div., Box 2001, Terminal Annex, Los Angeles 54, Calif.

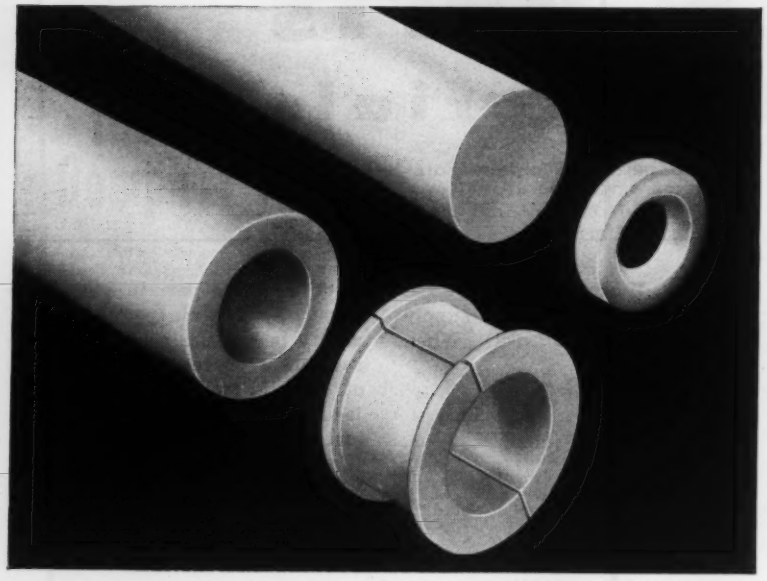
Circle 454 on page 19

Solder-Filled Connector

subminiature units contain own solder

Solder-filled contact for miniature and subminiature connectors has pin and socket contact pre-filled with solder alloy of any specified composition. Solid solder core

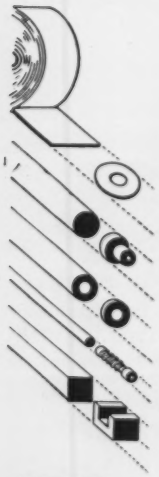
POLYPENCO® NYLON SHAPES



For Your Nylon Precision Parts . . . Accurate, Low Cost Machining

Above are two Polypenco Nylon Stock Shapes and parts machined from them. Machining was done on standard metalworking tools . . . rapidly, simply, and to close tolerances.

The use of nylon for parts such as this valve seat and split bearing continues to increase. This is because designers are becoming aware of the economy and ease with which such resilient, long-wearing, low friction parts can be machined from Polypenco Nylon Shapes.



POLYPENCO SHAPES ARE ADAPTABLE
Polypenco Nylon is produced in mill shapes for conversion by machining into a high variety of dimensions and shapes.

YOU CONTROL PRODUCTION
You have direct control over every phase of production, and change of design can be immediate with no extra costs involved. Stocks are available in major cities throughout the country.

YOU MAINTAIN HIGH QUALITY
Polypenco Nylon Shapes are manufactured under rigid quality control with uniform density, dimensional stability and freedom from porosity and stress spots.

Get design flexibility and production economy with Polypenco Nylon in Rod, Bar, Tubular Bar, Hexagonal Bar, Strip or Slab. Write today for data and specifications.

THE POLYMER CORPORATION OF PENNA. • Reading, Penna.
Export: Polypenco, Inc., Reading, Penna., U.S.A.

Custom Fabricated Parts supplied on request

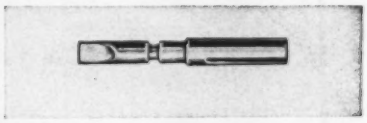
POLYPENCO Nylon, Teflon*, Q-200.5 and K-51

*DU PONT TRADEMARK

Circle 567 on page 19

New Parts

eliminates overflow of solder and possibility of breakage due to an excess of solder drawn by the wire. Installation requires only application of heat and insertion of wire.



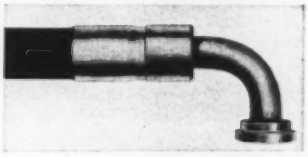
Noncorrosive resin flux in solidified form on surface of each cup eliminates need for tinning or adding flux during soldering operation and provides resistance to internal tarnishing. **DeJur Amsco Corp.**, Electronic Sales Div., 45-01 Northern Blvd., Long Island City 1, N. Y.

Circle 455 on page 19

Flange Coupling

has 360 deg swivel joint

Four-bolt split-flange pressed-on coupling has 360 deg swivel joint for maximum convenience in positioning and installing. Nonthreaded swivel has leak-proof O-ring seal. Unit eliminates pipe threading operations, separate union and swivel connectors, gas-



kets and sealing compound. Joint may be connected and disconnected repeatedly without developing leaks. Assembly is available in a range of sizes from ½-in. to 1½-in. and in standard bends from 0 to 90 deg. **Anchor Coupling Co. Inc.**, 342 N. Fourth St., Libertyville, Ill.

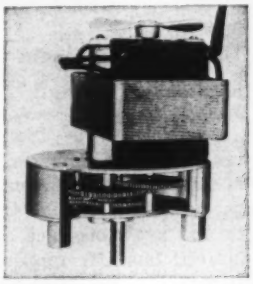
Circle 456 on page 19

Miniature Gearmotor

offers speed ratios to 2,592,000 to 1

Gear box of Series 500 fractional-horsepower motor has range of final shaft speeds supplied through standard gearing from 4.5 to 1 through 2,592,000 to 1. Final shaft speeds with standard motor are 600 rpm to 1 revolution in

seven days. Speeds between these limits are available in virtually continuous range, although not all torques are available in all shaft speeds. Motor operates on ac only at all normal voltages and on 25, 50 or 60-cycle current. Either



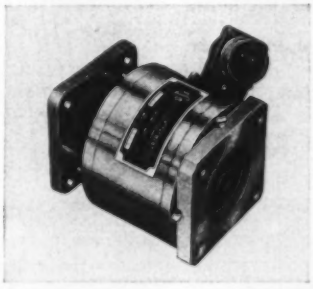
synchronous or nonsynchronous motors are available. Motors can be built as reversing motors or ganged to produce higher power. Due to design of winding, motors may be stalled indefinitely with current on without harm. Size of unit is 2⅛ in. by 2⅞ in. by 2⅝ in. **Gleason-Avery Inc.,** 45 Aurelius St., Auburn, N. Y.

Circle 457 on page 19

Tachometer Pickup

for frequencies to 240 cycles per second

Tachometer pickup provides high-frequency signal required for operation of electronic tachometers and frequency counters for aircraft engine and similar installations. Design of impulse generator



provides multiple magnetic paths (up to 120) which are simultaneously interrupted by rotation of a multi-toothed rotor operated within plane of a multi-toothed stator. Cylindrical magnet, magnetized parallel to its axis, provides uniform flux density through the paths and the averaging effect pro-

You Can be Sure of 2 WAY BENEFITS PRODUCTION PROFITS When You Use DPS POWER SCREWDRIVERS and other Assembling Equipment

Present Owners Report a SHARP GAIN in OUTPUT and a RISE in PROFITS!

Important Reasons why you, too, should benefit from greatly stepped-up, lower-cost production and the wider profit margin that naturally follows . . . These 2-way advantages of DPS Power Methods have been proved in over a quarter century of service to modern industry . . . If you are still using out-moded assembling methods, change now . . . Get the facts about the extensive DPS line. No doubt we have a product that can be adapted to your requirements. Write today.

BARREL FEEDER with stationary ring cover, for heavy-duty, large production runs

DPS SELECTIVE PARTS FEEDERS

Modern Necessities Widely Adaptable

These versatile devices not only provide the feeding operations on Detroit Power Screwdrivers, but they are being widely used on today's many special high-production machines.

BOWL FEEDER Vibratory type, to select and feed smaller fragile parts

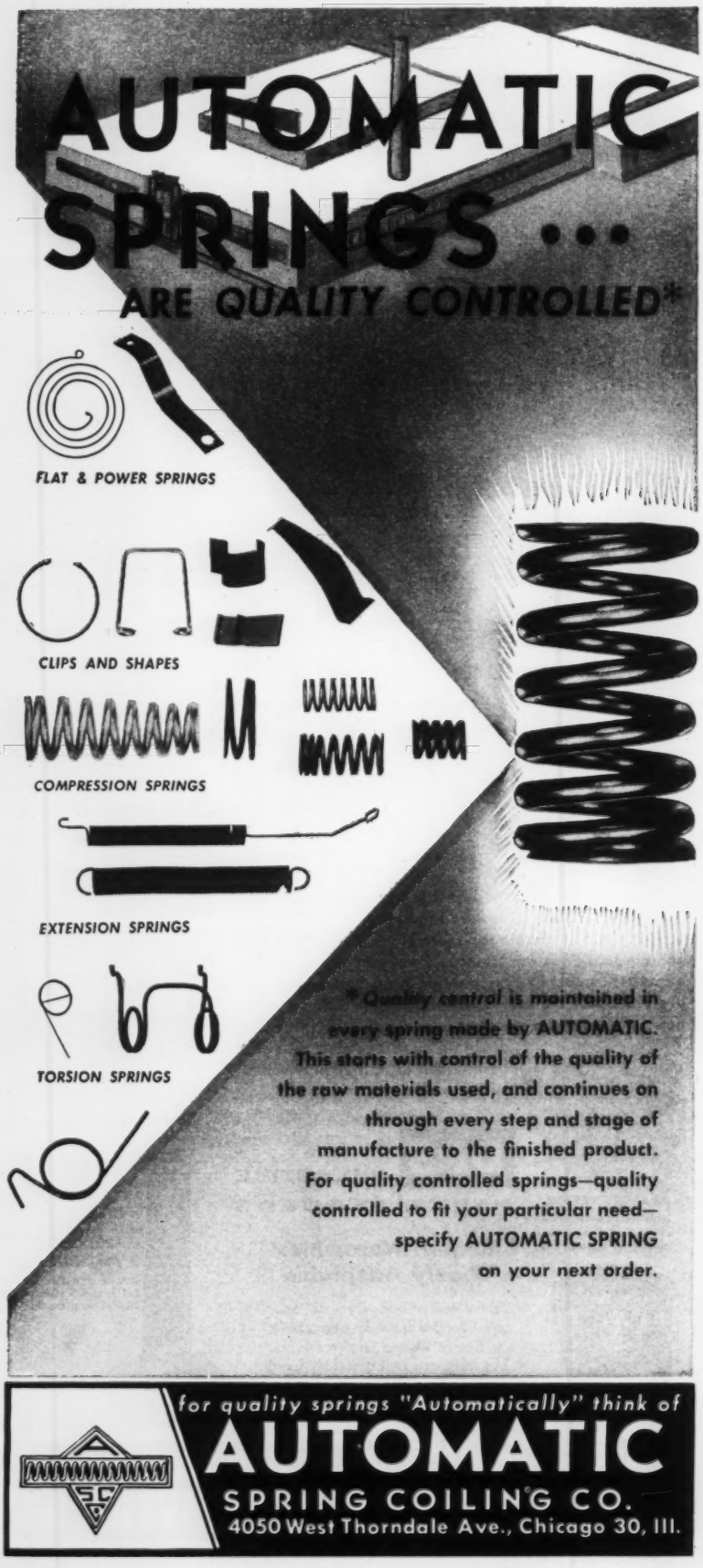
5 SCREW-DRIVING MACHINES Bench and Pedestal types. Pedestal Model A pictured

WHAT IS YOUR FEEDING AND ASSEMBLING PROBLEM? WRITE US—ALSO SEND SAMPLE ASSEMBLY

DETROIT POWER SCREWDRIVER CO.

2801-A W. FORT ST. DETROIT 16, MICHIGAN

Circle 568 on page 19


AUTOMATIC SPRINGS ...
ARE QUALITY CONTROLLED*
FLAT & POWER SPRINGS
CLIPS AND SHAPES
COMPRESSION SPRINGS
EXTENSION SPRINGS
TORSION SPRINGS
* Quality control is maintained in every spring made by AUTOMATIC. This starts with control of the quality of the raw materials used, and continues on through every step and stage of manufacture to the finished product. For quality controlled springs—quality controlled to fit your particular need—specify AUTOMATIC SPRING on your next order.
for quality springs "Automatically" think of
AUTOMATIC
SPRING COILING CO.
4050 West Thorndale Ave., Chicago 30, Ill.

New Parts

vides high-level signal output at low rotative speeds with minimum modulations. Wave voltage is 1 v rms at 100 rpm with speeds to 10,000 rpm available. **I-L-S Instrument Corp.**, 10701 Briggs Rd., Cleveland 11, O.

Circle 458 on page 19

Resin Glass-Mat Laminate

has high impact strength and flame resistance

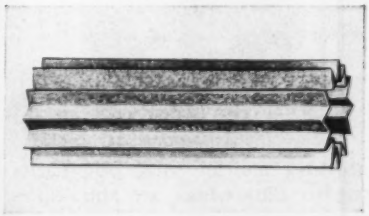
Polyester glass mat laminate, identified as GP-9204, has dimensional stability, exceptionally high impact strength and arc resistance of 180 sec. Material has UL approval as a flame-resistant material and is approved for sole support of current carrying parts at temperatures up to 150 C. Laminate has good dielectric loss properties under dry conditions and reasonably good dielectric strength under wet conditions. Chemical resistance to most acids and solvents, such as carbon tetrachloride, toluene, gasoline, and ethyl alcohol, is good. Applications are in areas of high humidity and around chemical fumes of an acid nature for use such as supports, panels, cams, armature slot wedges, spacers, switchboard panels, switch insulators, and arc chutes. Sheet sizes are 32 by 36 in., 32 by 48 in., and 32 by 74 in. **National Vulcanized Fibre Co.**, 1056 Beech St., Wilmington 99, Del.

Circle 459 on page 19

Filter Elements

for oil or air

Porous metal oil filter elements, made of powdered bronze, are de-



signed to filter out harmful solids and contaminants in hydraulic and pneumatic systems. Processing methods permit production of porous bronze filters with maximum filtering area within allowable di-

Circle 569 on page 19

HOW A YOUNG DESIGN ENGINEER PUT BETTER QUALITY INTO HIS PRODUCT

No single type washer can do the right locking job on all applications!

We need the right washers for every job... **LOCK** washers that really **LOCK**... such as **SHAKEPROOF'S** job-tailored line

for example, among **SHAKEPROOF'S** nine standards, the countersunk lock washer keeps countersunk screws locked tight!... Or, use the dome type for soft or thin materials and oversize or elongated holes.

for special problems and special savings... **SHAKEPROOF** "Specials" have practically no limit in design or application!

All **SHAKEPROOF**® Lock Washers have tapered-twisted teeth that bite deep, set up strut and spring action to resist backward rotation, **A PERFECT LOCK EVERY TIME!**

So next time use **SHAKEPROOF LOCK WASHERS**

The "job-right" lock washer locks tight every time

Improve quality... **CUT COSTS!**

SEND FOR SHAKEPROOF SAMPLER

Write today for SHAKEPROOF LOCK WASHER samples and useful "How to Choose" booklet!

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SHAKEPROOF
FASTEX

DIVISIONS OF ILLINOIS TOOL WORKS
World's Broadest Line of Micro-Assembly Fastenings

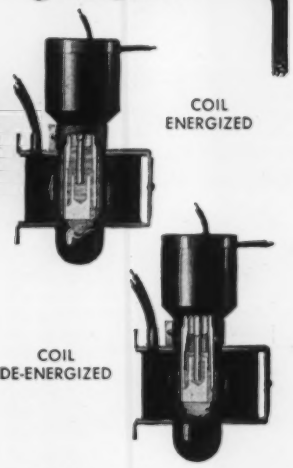
Circle 570 on page 19

The
TIMER RELAY
that eliminates controlled timing problems

★ No false contacts
★ Non sticking
★ Practically "fail safe"
★ Low cost timer

Durakool
STEEL MERCURY TIMERS

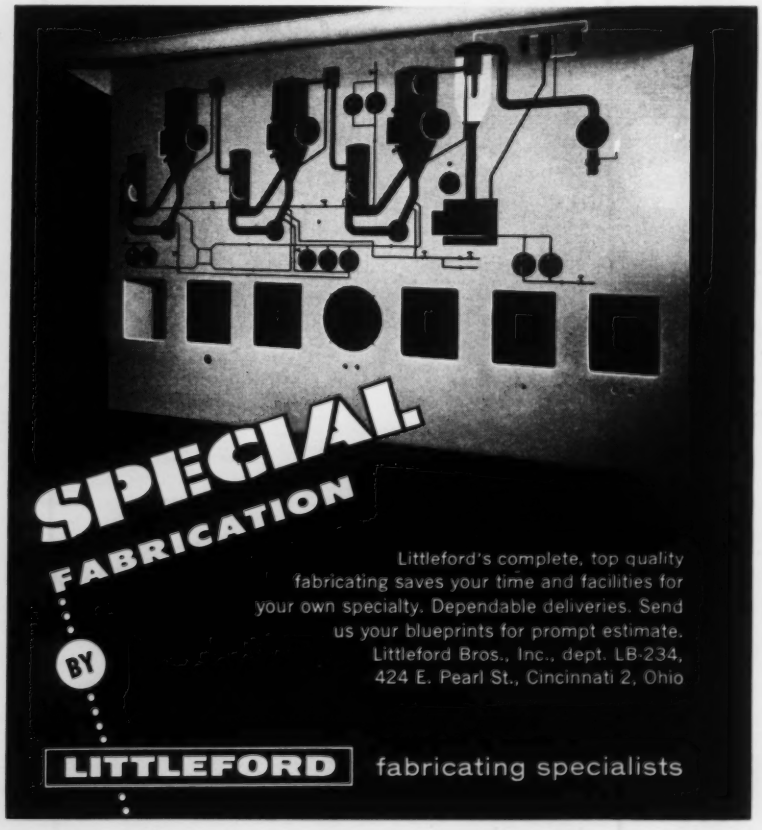
This steel clad, factory set, tamper proof Durakool timer-relay is practically non-breakable. Operating life multiplied 5 to 6 times by new plunger construction features. Any combination of operate-release time delays from 0.15 sec. to 20 sec.— either normally open or normally closed action.



See telephone directory for local distributor, or write.
DURAKOOL, INC.
ELKHART, INDIANA, U.S.A.
700 WESTON RD., TORONTO 9, CANADA

Send for Bulletin 800

Circle 571 on page 19



Littleford's complete, top quality fabricating saves your time and facilities for your own specialty. Dependable deliveries. Send us your blueprints for prompt estimate. Littleford Bros., Inc., dept. LB-234, 424 E. Pearl St., Cincinnati 2, Ohio

Circle 572 on page 19

New Parts

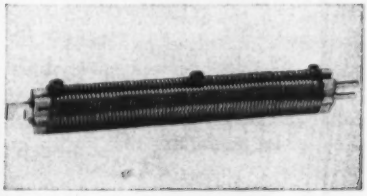
mensions. Design illustrated provides largest possible surface filtering area with added depth of filtration and controlled porosity and is typical of large range of sizes and shapes of filters in all grades of powdered metal. Filters are made to customer's specifications in grades of particle-size removal from 2 microns up to 151 microns. **Arrow Sintered Products Co.**, 1966 S. Kostner Ave., Chicago 23, Ill.

Circle 460 on page 19

Power Type Resistor

for high current and low resistance

Resistor for high-current, low-resistance applications consists of ceramic insulators assembled on a metal bar and wound with resistance alloy wire. Design provides

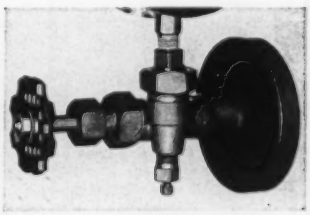


flexibility and resistance to shock with efficient heat dissipation. Resistance value range is 0.69 to 25 ohms; current range is 5.1 to 18.4 amp. Resistor is available in four lengths; the longest is 16¼ in. between mounting centers. Brackets and terminals are plated to prevent oxidation. **Ohmite Mfg. Co.**, 3649 Howard St., Skokie, Ill.

Circle 461 on page 19

Block Valve

eliminates need of threaded fittings



Valve for instrument piping and general use greatly reduces number of threaded connections required for installation. Unit is an

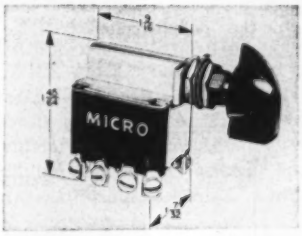
offset valve with a vertical rising ball check on downstream side of seat and with solid shank connection to vessel which makes it usable as block or root valve. Valve combines unions, nipples, reducers, elbows, tees, valve and drain valve into one unit. Unit has double seating stem (for repacking under pressure), pressure bleeder valve and test gage connection. Seats are regrindable and renewable. Valve has union connection for gage. **Jerguson Gage & Valve Co.**, 80 Fellsway, Somerville 45, Mass.

Circle 462 on page 19

Rotary Switch

handles many circuits simultaneously

Rotary toggle switch handles high electrical load, controlling many circuits with single motion, mechanical actuation. Electrical capacity eliminates necessity of relays or similar devices. Unit is



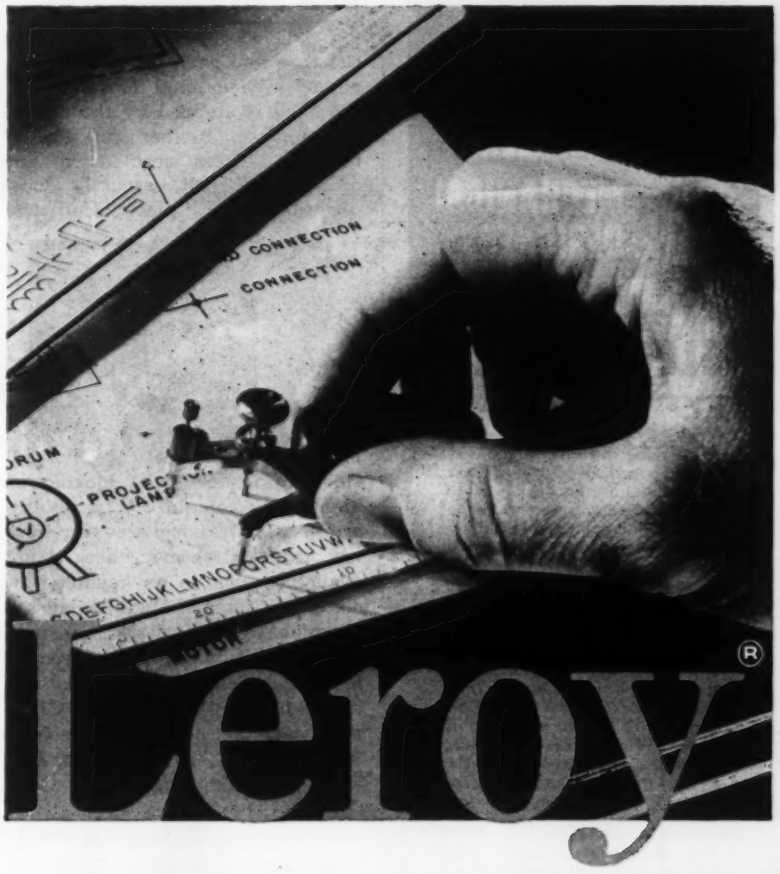
rugged enough for industrial and airborne applications. Four-pole, double-throw switch has three actuation positions (on-off-on) and 12 terminals. Operating force required is 9 in.-lb max. Electrical rating is continuous capacity 30 v dc, 20 amp resistive, 5 amp lamp or 12 amp inductive. At 115 v ac, rating is 20 amp resistive, 4 amp lamp and 15 amp inductive. **Minneapolis-Honeywell Regulator Co.**, Micro Switch Div., Freeport, Ill.

Circle 463 on page 19

Washer-Nut

is self-locking

Washer-nut is all metal self-locking unit with integral washer. Self-locking design consists of a split threaded core keyed into a hexagonal shell. Tapered shape of



makes hand lettering old fashioned

Its speed and uniformity is standard in modern drafting rooms—Legible reproduction of lettering is a must. But perfect hand lettering takes time and skill, and both cost big money these days. That's why thousands of modern drafting rooms have adopted Leroy® lettering—a K&E development—as standard on all jobs.

Leroy lettering can't help but be perfect regardless of the job or the experience of the man. Each letter is completely and uniformly produced in one quick, simple operation. It's so exact, yet so simple, that one man can start the job and another finish it without any variation in lettering. Because the lettering template is the same, there's almost no room for mistakes.

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Circle 573 on page 19

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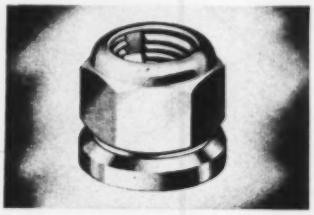
DIVISION OF BENDIX AVIATION CORP.
BALTIMORE 4, MARYLAND
Radio

Circle 574 on page 19

New Parts

the core and shell provide a collet action. When axial movement of the shell is stopped by the assembly surface, further rotation of the nut forces core down and around the bolt, securely locking the nut in place. Sufficient



movement of the core is provided to insure equal locking on high or low tolerance bolts. Washer provides adequate strength where full nut bearing area is not available, such as on keyhole-type mounting flanges and similar applications on generators, starters, and alternators. Maximum recommended temperature for installation is 550 F. Washer-nut is C1137 steel, cadmium plated, in sizes from ¼-28 to 7/16-20. **Delron Co. Inc.,** 5224 Southern Ave., South Gate, Calif.

Circle 464 on page 19

Silicon Rectifier

miniature unit has 1500 v capacity

Four types of 1500 v single element grown junction rectifiers feature welded case construction and high operating voltage. Miniature units operate stably from −55 to +150 C and have forward current ratings to 125 ma. Rectifiers

are available in two types of axial and stud half-wave models. Axial models allow point-to-point wiring. Stud models are designed for maximum heat dissipation. Available with either anode or cathode stud, units eliminate necessity for high voltage insulation between stud and chassis. Hermetically sealed

The abbot and the "Popping Plugs"

The *abbot* re-read the note, "Electronic Computer Manufacturer "X" is having trouble keeping plugs from popping out of jacks. Complex servomechanisms and controls are being thrown out of whack as a result. Sound interesting?"

The abbot's Solution: Use an Abbott bearing ball as a spring-loaded detent ball to hold the plug securely in its receptacle. Result: 20 lbs. pull needed to remove it, *and* an end to the problem of the "popping plugs."

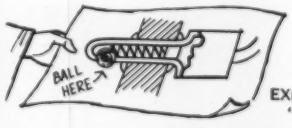


EXHIBIT "A"

Abbott carbon steel bearing balls serve many needs because they are Deep Hardened and Tempered. This makes them perform efficiently under high load factors and gives them increased shock resistance. These qualities amply justify the name . . . ABBOTT — "the Ball with the Armored Heart."

Write for "Case Histories from the Files of the abbot". It contains useful data and amusing reading.

ABBOTT

The ABBOTT BALL Company
50 Railroad Place, Hartford 10, Conn.

Circle 575 on page 19

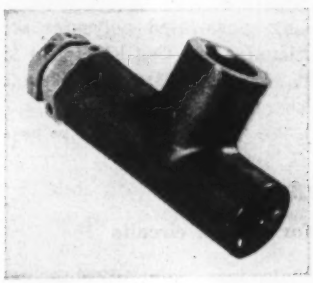
welded-case construction assures freedom from contamination and maximum reliability and stability. **Texas Instruments Inc.**, 6000 Lemmon Ave., Dallas 9, Tex.

Circle 465 on page 19

Relief Valves

hydraulic units handle 3850 psi

Relief valves function as thermal relief or main relief valves for hydraulic circuits. Model EA1160 has range of 2300 to 3850 psi with flows of 15cc to 1.2 gpm. Model



EA1164 has range of 1000 to 2000 psi with flows of 15cc to 1.2 gpm. Both models comply with Envelope AN6245, weigh 2½ oz and are available with 7/16-20 NF-3 threads or ¼-in. NPT. Various modifications of these valves are available to permit use in high-temperature applications. **Electrol Inc.**, Kingston, N. Y.

Circle 466 on page 19

Pushbutton Switch

has interchangeable components

Pushbutton control switch, rated at 600 v ac or dc, is dust, oil, and water-tight. Meeting all JIC and NMTBA specifications, switch is designed for wide range of applications. Designed to fit 1 13/64 in. holes on standard panel mounting centers, switch accommodates panel thicknesses from 1/16 to ¼-in. Units and components are completely interchangeable, available in flush-plate or box-type mountings and permit any combination of pushbutton, selector, or pilot light assemblies. Single and double pole contact blocks may be used with the switch, both having heavy-duty terminal screws for ready

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are being used in the power plants, gyro- and servo-mechanisms, and on various other types of equipment. Production orders may run into thousands of pieces or as few as desired.
Parts that must resist the terrific temperatures encountered are being cast in the excellent heat-resistant alloys like Hastelloy, Stellite and Inconel. Ferrous and non-ferrous alloys are investment cast in shapes too costly to fabricate by other manufacturing methods.
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Circle 576 on page 19

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Circle 577 on page 19

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Circle 578 on page 19

New Parts

and permanent securing of wiring. Interchangeable collars are supplied in three heights to enable

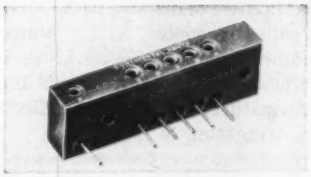
changing from flush to extended-type button. Buttons are available in an assortment of colors in non-fading glass-filled polyester resin. **National Acme Co.,** Electrical Mfg. Div., 170 E. 131st St., Cleveland 8, O.

Circle 467 on page 19

Test Connector

for printed circuits

Female test point receptacle for printed circuit wiring will accept and hold standard 0.080-in. test probe. Molded body is mineral-filled Melamine, designed for right-



angle mounting. Six floating-type contacts are made of spring-temper phosphor bronze, gold plated over silver for low contact resistance and ease of soldering. **DeJur-Amsco Corp.,** Electronic Sales Div., 45-01 Northern Blvd., Long Island City 1, N. Y.

Circle 468 on page 19

Air-Cooled Engine

delivers 70 hp at 3000 rpm

Compact valve-in-head, air-cooled four-cylinder vee-type engine is designed for general applications in industrial, agricultural, and construction fields. Designated model CV4-180, engine delivers 70 hp at 3000 rpm. Engine features parts interchangeable with earlier 30 hp unit, including aluminum cylinder

head, cylinder barrels, pistons, connecting rods, bearings, and valves. Engine has full pressure lubricating system, four-throw three-main-bearing counterbalanced

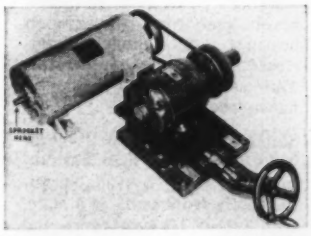
crankshaft, and twin three-bearing camshafts. Engine accessories are flange mounted and gear-driven from timing gear train. Bore and stroke are 4 in. by 3½ in.; displacement is 176 cu in.; and engine weight less housing is 463 lb. **Avco Mfg. Corp.,** Lycoming Div., 550 S. Main St., Stratford, Conn.

Circle 469 on page 19

Winding Motor

offers variable tension at 1 to 1200 rpm

Winding motor is designed primarily to maintain constant tension at extremely low speeds on a winding drum. Unit consists of an electric differential, a variable speed unit, and a ½-hp motor. Differential has a rotating stator driven through the variable-speed unit in the direction opposite that required to wind. With the stator held stationary, the output shaft of the differential turns in the di-



rection of winding. Variable-speed pulleys are supplied to suit speed range and tension desired. Tension is varied by adjusting stator speed of differential. For lighter tension, the speed is increased; for increased tension, the speed is reduced. Electrical differential winding motor is 19⅜ in. long and 7½ in. diam; both input and output

Lubrication
WITH A "SENSE" OF DIRECTION

Photo courtesy Western Gear Corporation, Seattle, Washington

Reversing machinery like these autoclave drive units must be protected with positive lubrication regardless of the direction of shaft rotation. To insure this, Western Gear engineers required a lubrication pump that would reverse automatically whenever the drive shaft changed rotation. They selected the Tuthill Model R rotary, internal-gear, positive displacement pump for this application because of its exclusive automatic reversing feature. The Model R can be driven in either direction of rotation without changing the direction of oil flow or port positions, thus giving reversing equipment the most dependable lubrication protection possible.

In addition to standard pumps like these, Tuthill service includes the design, development and manufacture of special pumps to fit your individual needs. By taking advantage of Tuthill's custom engineering, you can avoid compromising the design of your product.

Write for Bulletin No. 105 on Tuthill Reversing Pumps or data on other types to fit your specific requirements.

TUTHILL PUMP COMPANY

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Circle 579 on page 19

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Please send complete specification data and samples of your aluminum fasteners.

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Always fasten aluminum with ALCOA® Aluminum Fasteners

Circle 580 on page 19

New Parts

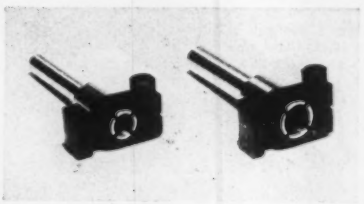
shafts are 0.709-in. diam. Unit is wired for 220, 440 or 550-v, 3 phase, 60 cycle, ac. **Hobbs Mfg. Co.**, 26 Salisbury St., Worcester, Mass.

Circle 470 on page 19

Shaft Extensions

fit shafts from ⅛ to ¼-in.

Stainless-steel shaft extensions are ground on centers to maintain high accuracy of concentricity between ends. Extensions allow male and



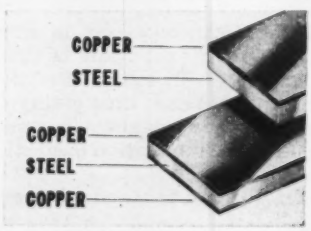
female connections between any combination of ⅛, $\frac{3}{16}$, and ¼-in. rotating component and shaft. **PIC Design Corp.**, P. O. Box C, East Rockaway, L. I., N. Y.

Circle 471 on page 19

Clad Metal

is copper-clad hardenable steel

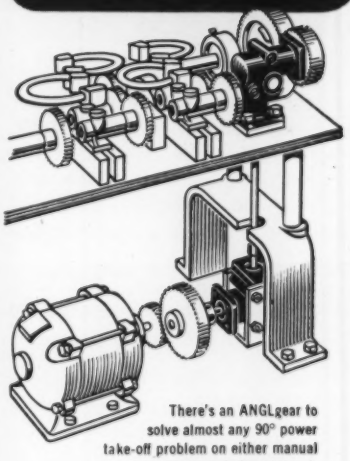
Clad metal consists of medium carbon hardenable steel (SAE-1065) clad on one or both sides with oxygen-free, high conductivity copper (OFHC). Metals are inseparably bonded by solid-phase bonding process without use of brazing alloys or other intermedi-



ate materials. Composite metal has continuous permanent bond, high conductivity, excellent spring characteristics by heat treatment, resistance to corrosion, ductility for extreme forming with long tool wear, and good operating characteristics at temperatures below tempering range. Standard

ANGLgear

simple
compact
positive
90° drive



There's an ANGLgear to solve almost any 90° power take-off problem on either manual or power operated equipment.

In the application illustrated two ANGLgears provide a simple, compact, *positive* 90° drive. Because of its optional mounting features, ANGLgear was easy to design into this application.

ANGLgear combines light weight with high capacity. Model R-320, for instance, weighs only 2.2 lb., yet will transmit a torque of 1500 lb. in.

ANGLgear has no exposed working parts. Its hardened bevel gears and antifriction bearings are completely enclosed, permanently lubricated. This assures virtually maintenance-free service.

Standardized ANGLgear — always less costly than custom-made drives — is available immediately from stock in 3 sizes, with 1-1 or 2-1 gear ratios and 2- or 3-way shafting. See our data in Sweet's Product Design File; then contact your local distributor or write us.

AIRBORNE®
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HILLSIDE 5, NEW JERSEY

Circle 581 on page 19

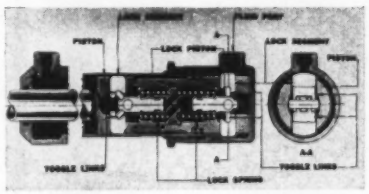
cladding ratio with copper on one side is steel/copper ratio of 80/20. Standard ratio with copper on both sides is 10/80/10. Other ratios available are 90/10, 70/30, 5/90/5, and 20/60/20. Applications are fuse clips, connectors, switch components and similar electrical parts, and for non-electrical parts requiring excellent surface for electro-plated finishes. **Metals & Controls Corp.**, General Plate Div., 43 Forest St., Attleboro, Mass.

Circle 472 on page 19

Internal Locking Actuator

withstands 400,000 lb load

Hydraulic or pneumatic internal locking actuator provides positive locking both extended and retracted. Switches and sequence valves operate off lock. Unloading of toggle linkage is instantaneous to prevent damage to lock during un-



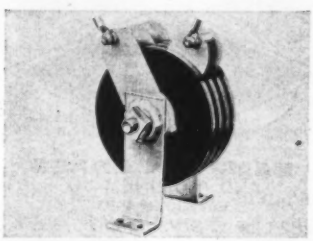
locking under high loads. Two-segment lock handles loads to 100,000 lb; four segment-lock handles loads to 400,000 lb. Unit is available in sizes 1 in. and larger for use at pressures to 5000 psi. **Tog-Loc Inc.**, P. O. Box 735, Bellevue, Wash.

Circle 473 on page 19

Discharge Varistor

protects against inductive surges

Discharge varistor assembly is a voltage sensitive nonlinear resistor



mounted for direct installation in electrical circuits. Available in

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- CHUCKS
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FILTER REMOVES SOLIDS, LIQUIDS, from compressed air. Choice of 64 or 25 micron filter element. Optional location of drain.

EXACT CONTROL OF AIR PRESSURE by relieving type air pressure regulator. 150 psi. max. primary pressure —adjustable range 0-125 psi.

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Model 33AG-4 Lubro-Control Unit
- Filter
- Regulator
- Lubricator

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QUICK MAINTENANCE No tools needed to reach filter element or to refill oil reservoir. Back cover is removable.

For complete information about the new 33AG-4 unit, call your nearby Norgren Representative listed in your telephone directory—or WRITE THE FACTORY FOR BROCHURE 558.

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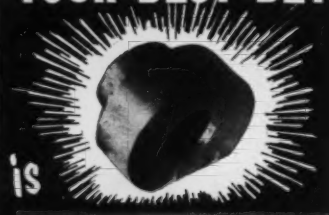

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Circle 583 on page 19

New Parts

ready-mounted groups of 1 to 4 varistors, each disk is 6 in. diam and 3/8-in. thick with a 1 in. central mounting hole. Disks are bracket mounted on a horizontal insulated bolt with spring washer to provide contact pressure. Spacers permit air circulation. Assembly is connected across the circuit of component to be protected. Continuous watts loss is about 2 per cent of equivalent fixed resistor offering equivalent protection. Unit is designed to protect motors, generators, electromagnetic devices, solenoids, relays, and large coils against high inductive surges from sudden interruption of inductive currents. **General Electric Co.**, Metallurgical Products Dept., Detroit 32, Mich.

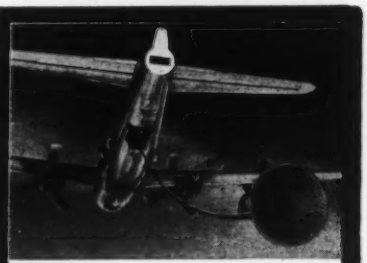
Circle 474 on page 19

Piston Seal

for cylinder applications up to 300 psi

Piston seal for air or fluid operated instruments and actuators is designed for applications to 300 psi. Acting as both bellows and constant area diaphragm, unit functions efficiently in assemblies that are not perfectly aligned or machined. Flange of seal operates as a gasket, sealing mating surfaces in cylinders of two-piece design. Impregnated fabrics give long life and resistance to fatigue and chemical action. Operation is practically free of friction or spring gradient, rolling action requires no lubrication and is not materially affected by finish or hardness of associated parts. Both accurate and sensitive, seal is free-positioning and has complete relaxation within its designed stroke. Seal is available in sizes for 1 in. to 6 in. cylinder bores. **Bellofram Corp.**, Burlington, Mass.

Circle 475 on page 19



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262 Liberty St.•Springfield, Mass.

Producers of Non-Ferrous Sand, Permanent Mold & Die Castings

Circle 584 on page 19

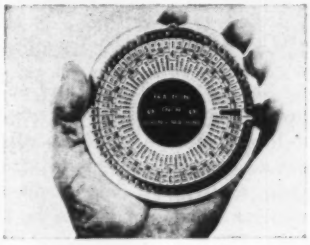
ENGINEERING DEPARTMENT

EQUIPMENT

Adding Device

handles fractions and decimal equivalents

Fraction of inch adding device in disk form permits continuous adding or subtracting of fractions, decimal equivalents, or mixed fractions and decimal equivalents. Op-



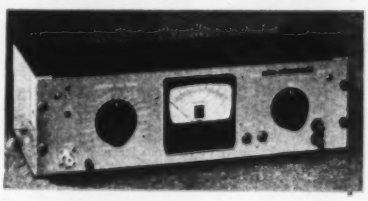
eration is simple and answers are shown instantly. Unit has only one moving part. Device is satin-finished aluminum, with numbers and lines etched and filled with black enamel. **Sheridan Advertising Specialties,** 26032 Grand River Ave., Detroit 19, Mich.

Circle 476 on page 19

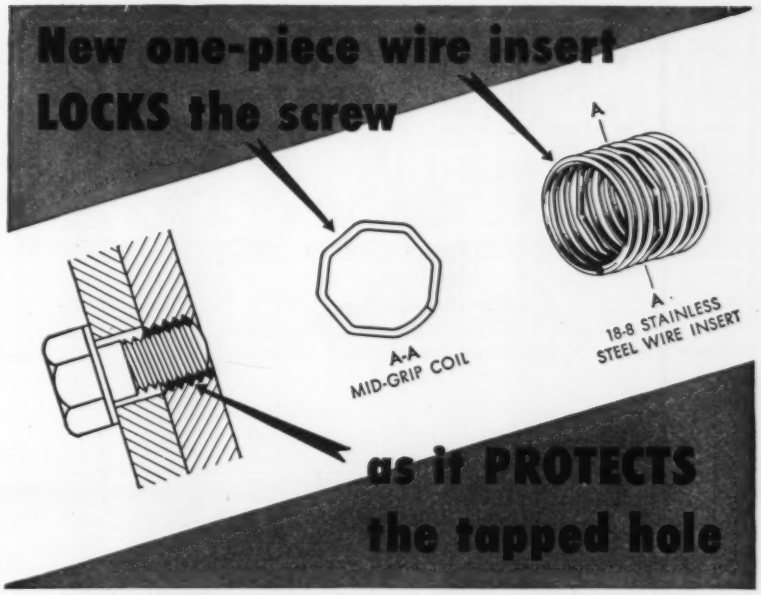
Micro-Microammeter

measures low currents over wide range

Micro-microammeter measures, records, and controls extremely low currents. Unit measures currents over 10 decades on 20 ranges from 1×10^{-3} to 3×10^{-13} amp full scale. Accuracy is ± 3 per cent or bet-



ter. Zero drift is less than 2 per cent full scale after 5 minute warm up, with less than 2 per cent in subsequent 24-hour period. Instrument can drive 1 ma or 5 ma, and 50 mv rebalancing type re-



Withstands vibration, heat, corrosion — Meets AN-N-5b lock nut specifications

Here is a ONE-PIECE stainless steel thread insert that will *lock the screw against loosening* as it permanently protects the tapped hole. The secret is in the Mid-Grip coil. Shaped like a polygon, its chords exert a spring pressure on the screw thread and prevent rotation at less-than-rated torque. No loss of torque occurs at elevated temperatures or after repeated disassemblies.

NO EXTRAS—The *Heli-Coil** Screw-Lock (Mid-Grip) Insert employs no locking rings, pins, plugs, tabs or wiring. It can be installed from the front or top. Think of the money — and assembly time — you can save!

NO PROJECTIONS — Screw-Lock Inserts furnish AN-N-5b lock nut torque *right down inside the parent piece* . . . eliminate costly weight and space . . . improve design.

NO WEAR, NO CORROSION — Like regular *Heli-Coil* Inserts, new Screw-Lock Inserts are made from 18-8 stainless steel wire, and normally outlast the unit they protect. They permit smaller, fewer fastenings, and require minimum surrounding material. Screw-Lock Inserts are available in popular NC and NF sizes with choice of two lengths.

Mail coupon for complete data—or better still, see Yellow Pages of your phone directory — "Inserts — Screw Thread" for name of your local Heli-Coil Applications Engineer. Call him now!

Regular *Heli-Coil* Inserts (no locking action) put corrosion-proof, strip-proof stainless steel threads in soft materials . . . permit smaller, fewer fastenings, lighter weight, reduced cost.

HELI-COIL **SCREW-LOCK INSERTS**

Products of Heli-Coil Corporation, Danbury, Conn.

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131 Shelter Rock Lane, Danbury, Conn.

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☐ Send design manual on standard *Heli-Coil* Screw Thread Inserts.
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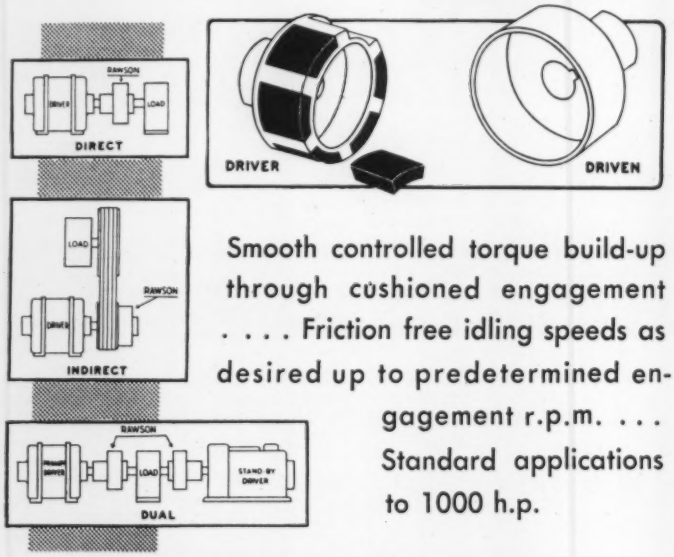
IN CANADA: W. R. Watkins Co., Ltd., 41 Kipling Ave. S., Toronto 18, Ont.

Circle 585 on page 19

RAWSON® AUTOMATIC CENTRIFUGAL CLUTCH



Smooth controlled torque build-up through cushioned engagement . . . . Friction free idling speeds as desired up to predetermined engagement r.p.m. . . . Standard applications to 1000 h.p.

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Circle 586 on page 19

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World's Foremost Producer of Small Die Castings

Circle 587 on page 19

Engineering Equipment

corders. It has a regulated tap of about 250 v for polarizing ion chambers. **Keithley Instruments Inc.**, 12415 Euclid Ave., Cleveland 6.

Circle 477 on page 19

Drafting Table

in sizes to 42 x 84 in.

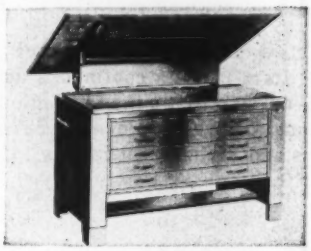


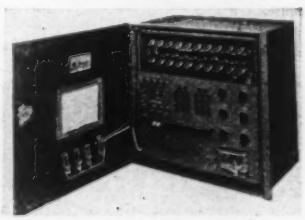
Table has all metal base and solid basswood top with metal edges. Foot lever releases brake to allow height adjustment of table top from 36½ in. to 45½ in. Hand-lever release allows angle of top to be adjusted. Book shelf, reference top, drawer unit, and plan file are among auxiliary units available. Top sizes range from 37½ by 48 in. to 42 by 84 in. **Mayline Co.**, 619 N. Commerce St., Sheboygan, Wis.

Circle 478 on page 19

Digital Converter

drives X-Y plotter from digital input

Digital readouts, such as those from punched-tape equipment, are converted to X-Y plotter-input form by this digital converter. Switches on converter determine



words and digits to be plotted, eliminating need for programming on tape. Reader operates at 20 characteristics per sec; maximum plotting speed is 40 points per minute. **Librascope Inc.**, 808 Western Ave., Glendale 1, Calif.

Circle 479 on page 19

THE ENGINEER'S

Library

Recent Books

Resistance Welding Theory and Use. *157 pages, 6 by 9 in., clothbound; prepared by Resistance Welding Committee, American Welding Society; published by Reinhold Publishing Corp., 430 Park Ave., New York 22, N. Y.; available from* MACHINE DESIGN, *$4.50 postpaid.*

This book covers every aspect of resistance welding from basic principles to most effective use. Newest developments such as slope control and aluminum welding are presented, as are processes, equipment, precautions, quality control, inspection and testing. Resistance welding methods discussed are spot, seam, projection, flash, upset and percussion. Further chapters are concerned with welding symbols, weldability of various metals, and specification and qualification procedures.

•

Machinists' Ready Reference. *Compiled by C. Weingartner; 139 pages, 4 by 6 in., wirebound; published by and available from Prakken Publications, 330 Thompson St., Ann Arbor, Mich.; $1.50 per copy.*

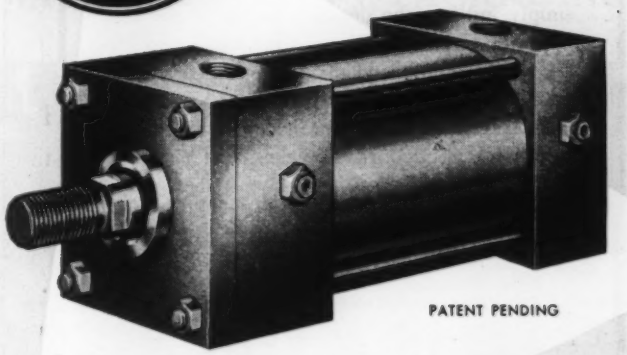
Although intended primarily as a machinist's booklet, this guide presents a large amount of material useful to the designer in a handy, concise manner. Included are tables on small cutting tool standards, tapers, screw threads, machining operations, gearing, sheet metal gages, tolerances, weights of materials, and mathematical tables.

•

A Manual of Engineering Geometry and Graphics for Students and Draftsmen. *By Hollie W. Shupe, professor of engineering drawing, and Paul E. Machovina, associate professor of engineering drawing, both of Ohio State University; 341 pages, 6 by 9 in., clothbound; published by McGraw-Hill*

FOR AUTOMATION

SP CYLINDERS



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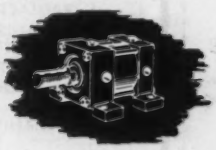

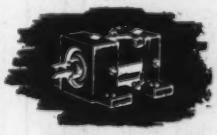

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The Engineer's Library

Book Co. Inc., 330 W. 42nd St., New York 36, N. Y.; available from MACHINE DESIGN, *$5.25 postpaid.*

The material in this book includes the fundamentals of orthographic projection and their use in the solution of geometric problems of line and surface relationships, vectors, functional scales and their applications in conversion and sliding scales, alignment charts, curve fitting, and graphic calculus. Fundamentals are emphasized and treatments generalized to permit wide latitude in applications. Problems are grouped so that those involving one type of surface are together by type, making location rapid.

Government Publications

Electrolytic Grinding of Hard Metals and Carbides, PB 111834. *By I. Weber, Frankford Arsenal; 35 pages, 8 by 10½ in., paperbound, side-stapled; available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.; $1.25 per copy.*

This booklet reports on investigations of electrolytic grinding in which the work is set-up as an anode in a dc circuit, and is held against a metal-bonded abrasive wheel which forms the cathode. Grinding proceeds as a result of electrochemical solution of the anode. Suitable electrolytes and various parameters affecting grinding rate are discussed as well as wheel speed, rate of metal removal, and surface finish attained.

•

NACA Technical Series. *Each publication is 8 by 10½ in., paperbound, side-stapled; copies available from National Advisory Committee for Aeronautics, 1924 F St. N.W., Washington 25, D. C.*

The following Technical Notes are available:

3769. **Further Investigation of the Feasibility of the Freeze-Casting Method for Forming Full-Size Infiltrated Titanium Carbide Turbine Blades**—19 pages.

3801. **Experimental Investigation of the Strength of Multiweb Beams with Corrugated Webs**—17 pages.

3772. **Effect of Three Design Parameters on the Operating Characteristics of 75-Millimeter-Bore Cylindrical Roller Bearings at High Speeds**—37 pages.

3773. **The Design of Brittle-Material Blade Roots Based on Theory and Rupture Tests of Plastic Models**—46 pages.

New Machines

Metalworking

Cut-Off Machine: Model M-75 cut-off machine, specifically designed for cutting ferrous metals, is equipped with fully automatic bar stock feed and power stroked head for automatic production line work. Speeds of 550 cuts per hour are maintained during production runs, with tolerances held to less than 0.005-in. Wheel-wear compensator adjusts for fast approach and regulated speed of cutting operation by hydro check. Cutting head has geared-in-head positive drive. The unit cuts 1½ in. solid rounds easily. *Stone Machinery Co., Manlius, N. Y.*

Profiler and Contour Grinder: Heavy-duty unit is designed for the fast removal of metal on steel punch or heavy press die sections. It will precision grind large die sections to close specifications. Precision spindle supported by a heavy column and over-arm serves as the mounting for the grinding wheels, which range in size up to 6 in. in diam by 4 in. high. Power is supplied by a completely enclosed 2-hp motor, remotely controlled by pushbuttons and mounted on the over-arm at the top of the spindle housing. The grinding wheel can be tilted from zero to 5 deg by means of a handwheel adjustment and can be raised 10 in. above table level. A diamond dresser is an integral part of the machine, which is electrically equipped to JIC or NEMA standards. *Kindt-Collins Co., Cleveland.*

Radial Drill: Master 3 ft, 12 in. radial drill, which performs boring and reaming as well as drilling, is the smallest of a series of drills including also 4, 5, 6, 7 and 8 ft machines. The drill has a fixed arm which always remains at the same height and can be swung 360 deg. Machine is equipped with a motorized table, also able to swing 360 deg, that moves vertically on the column and places the workpiece at the appropriate height. The

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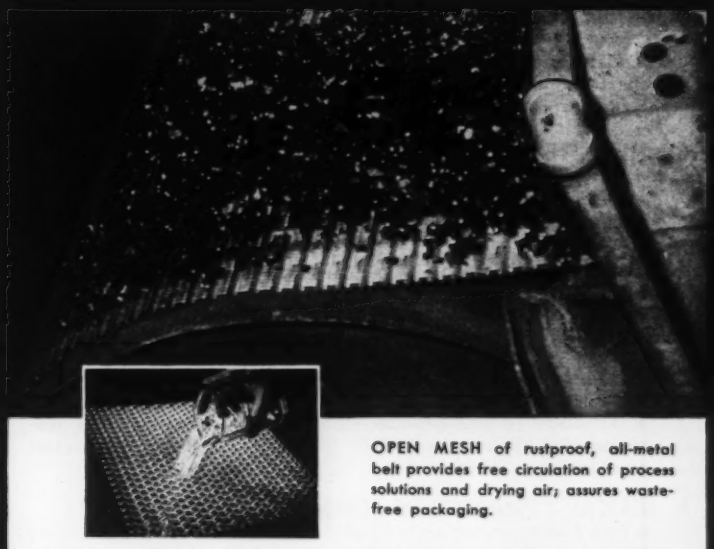

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Circle 589 on page 19

HELPFUL DESIGN INFORMATION

The articles listed below have been reprinted from MACHINE DESIGN and are now available at no charge from the Reader Service Department.

1. HYDRAULIC SYSTEM COMPONENTS
by W. T. Stephens
Points to consider in selecting hydraulic cylinders, motors, pumps, valves, connecting lines, reservoirs, and accumulators. (8 pages)

2. BRAKE DESIGN
by Reiner J. Auman
A data sheet which by means of vector analysis and design charts simplifies the block and shoe type brake design problems. (8 pages)

3. INVOLUTE GEAR TEETH
by Allan H. Candee
A new, simpler and more direct method of determining the thickness of involute gears—complete with tables. (12 pages)

4. CAM MECHANISMS
by Ray C. Johnson
Procedures for designing the optimum physical cam mechanisms for high speed machinery operation. (7 pages)

5. MULTIPLE-DISK CLUTCHES AND BRAKES
by Howard B. Huntress
A summary of multiple-disk clutches and brakes including discussions of application factors, torque relationships, mechanical considerations, and wet clutch design. (10 pages)

6. HELICAL COMPRESSION SPRINGS
by Edwin F. Smith
Helical compression spring design is simplified by use of an extensive series of tables. (12 pages)

7. ELECTRIC MOTOR BRAKING
by John C. Ponstingl
Factors to be considered in determining electric motor braking —primarily all-electrical methods are reviewed and compared with other braking processes. (11 pages)

8. GEAR RATIOS
by Arne Benson
A new graphic tool called the rational plane presents an easier solution to gear ratio problems. (12 pages)

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New Machines

table can be moved completely out of the way when the base is to be used for fixturing large workpieces. Raising and lowering of the table is by hand or pushbutton power. Fixed-arm design makes the machine well suited for precision boring. Hand wheel and fine hand wheel are available for advancing the spindle. Twelve spindle speeds from 60 to 2100 rpm are obtained through the preselector, with reverse speeds obtained instantly. Four spindle feeds can be selected by means of a feed and speed calculator located on the center of the head. All controls are centrally located on the head and arm support. *S & S Machinery Co., Brooklyn.*

Packaging

Stapler: Model CSC-1 machine staples tops or bottoms of corrugated and fiberboard boxes of any style after they have been packed. The unit is equipped with one stapling head and is air operated with fully pneumatic controls. It is equipped with air filters, lubricators, regulators and gages. Minimum air pressure requirement is 60 psi. The head can be rotated 90 deg to drive staple parallel to carton edge. Floor space requirement is 22 x 24 in. A hinged head and carton backstop are available as optional equipment. *Container Stapling Corp., Herrin, Ill.*

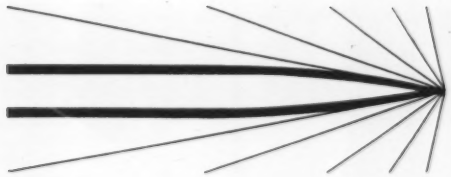
Packaging Machine: Model FH 400 automatic packaging machine seals up to 6000 items per hour to government specifications in individually printed envelopes, and prints, seals, packages and cuts off automatically. It semiautomatically feeds gaskets, slip-joint nuts, O-rings, bolts, small electronic parts, bearings, gears, valves or grommets from a hopper down a vibratory chute onto a moving strip of heat-sealable foil or paper. An upper strip of sealing material, automatically printed with specifications or other data, joins the lower strip at the sealing rolls where the pouch is heat-sealed on four sides and cut. The unit can accommodate a number of items in a single package through the use of a pocketed rotary conveyor. Variable-speed drive enables the

operator to slow up the sealing cycle while loading multiple items. Shift lever actuates the transmission to change ratio between the printer and cut-off and sealing rolls, permitting the operator to change bag size without additional set up except sleeve changing. The machine is equipped with interchangeable sleeves to handle products up to 6 in. OD by ¾-in. thick. *Product Packaging Engineering, Culver City, Calif.*

Processing

Marking Machine: Model 9AH marking machine accomplishes the multicolor marking of plastic, wood and painted metal parts and products. It is also adaptable to the marking of steel and other metal parts and products by detaching the heating elements and stopping the colored leaf feed. It uses flat dies to mark round parts by rotating or rolling the part; for flat parts a roll die is used. 110/220 v ac connection provides the heat for the marking dies and electrical controls. Air line connection of 125 psi is sufficient for continuous operation. *Acromark Co., Elizabeth, N. J.*

Injection Molding Machine: Model 701 two-ounce automatic machine molds, degates, ejects and sorts automatically, and is applicable to any material. Nylon can be molded without stringing or nozzle change. The unit molds decorated parts without damage to surfaces. Vertical clamping is combined with horizontal comb action. Varied parts are sorted automatically from combination molds. Horizontal comb action gives flexibility in parts ejection. Barriers can be incorporated in the comb to guide parts into separate bins. Hot runner molds provide positive shut-off at the mold and eliminate all projections at the gate. The machine permits top and bottom ejection of pieces. Knock-out cylinders are hydraulically operated, independent of moving ram. Anti-shock hydraulic system is self-contained and leakproof. All hydraulic and electrical circuits meet JIC specifications. Plasticizing capacity is 30 lb per hr. *F. J. Stokes Corp., Philadelphia.*



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GUIDANCE AND CONTROLS, encompassing research and development of advance automatic guidance and flight control systems for both missiles and piloted aircraft. Specific areas of development include: radio and radar systems, flight control systems, inertial guidance systems, instrument servo systems, digital computer and magnetic tape recording systems, airborne analogue computer systems, optical and mechanical systems, and systems test and analyzer equipment.

FLIGHT TEST ENGINEERING SECTION, which plans the missile test programs and establishes test data requirements in support of the programs. The data requirements are predicated on the test information required by the engineering analytical and design groups to develop and demonstrate the final missile design, and are the basis from which instrumentation requirements are formulated.

The analysis work performed consists of aerodynamic, missile systems, dynamics, flight control, propulsion and guidance evaluation. The Flight Test Engineering Section is also responsible for the field test program of the ground support equipment required for the missile.

FLIGHT TEST INSTRUMENTATION SECTION, which includes a Systems Engineering Group responsible for the system design concept; a Development Laboratory where electronic and electro-mechanical systems and components are developed; an Instrumentation Design Group for the detail design of test instrumentation components and systems; a Mechanic Laboratory where the instrumentation hardware is fabricated; and a Calibration and Test Group where the various instrumentation items and systems are calibrated and tested.

For 17 years Northrop Aircraft has pioneered in missile research and development. As a member of this forefront organization in this growing field, new opportunities for full expression of your initiative and ability will always be yours at Northrop.

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Browning MANUFACTURING COMPANY
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Circle 591 on page 19

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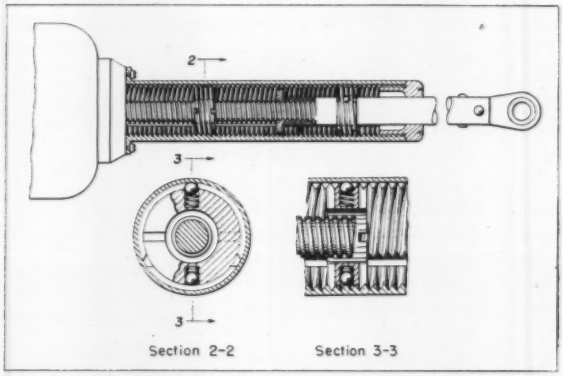
Circle 592 on page 19

NOTEWORTHY

Patents

Adjustable-Stroke Actuator

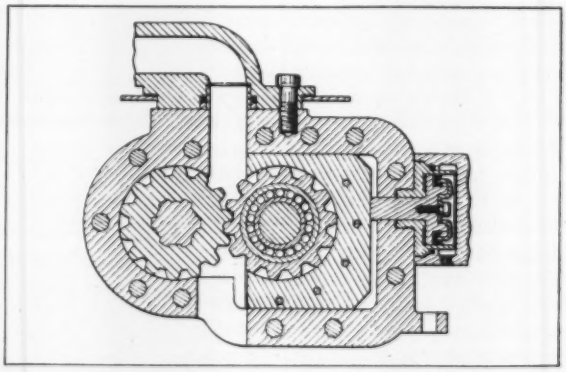
Convenient and accurate control of stroke limits of a linear actuator are provided by adjustable internal stop rings. Locked in position by ball-spring



detents, the rings contact the flanged end of the actuator rod to limit stroke of the actuator in either direction. Stop positions are changed by moving the rings along the internally threaded actuator housing. *Patent 2,746,314 assigned to General Dynamics Corp. by Howard W. Donovan.*

Variable-Displacement Pump

Drive-motor overloading due to excessive discharge pressure is prevented by a translating follower-gear arrangement in a variable-displacement, gear-type pump. Discharge pressure higher than a preset maximum moves the follower gear (right) away from



the drive gear (left), thereby increasing tooth clearances and bleeding the discharge pressure back to normal level. Translation of the follower-gear mounting block is opposed by an external piston working

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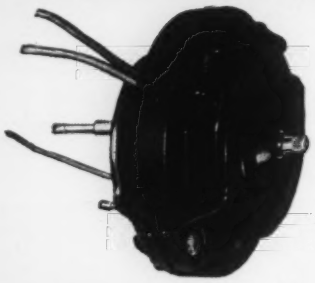

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Circle 593 on page 19

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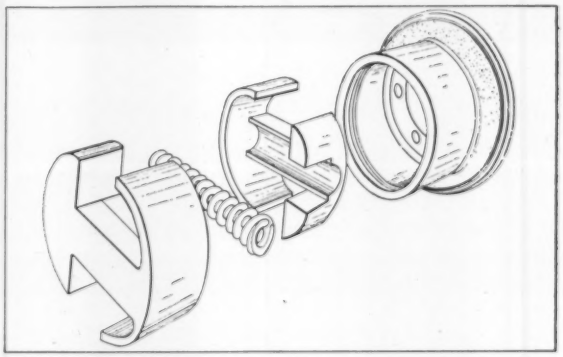
Noteworthy Patents

in a cylinder connected to a constant-pressure source. *Patent* 2,754,765 *assigned to Joy Mfg. Co. by Joseph F. Joy.*

Torque-Limiting Coupling

Mass distribution of nested friction shoes in a spring-loaded coupling can be arranged to either aid or oppose action of the spring, permitting application as either a centrifugally loaded or unloaded clutch. In normal torque-limiting service, imposition of over-



load torque causes slippage between driving and driven members. Thermal capacity of shoe and drum alloys permits continuous overload (slippage) without damage to unit. An external brake disk can be provided for application where auxiliary braking is desired. *Patent* 2,753,031 *assigned to General Motors Corp. by James W. Light.*

Plug valve, applicable for control of corrosive liquid flow, incorporates an inert plastic interliner which is locked by its noncircular outer periphery to prevent turning or twisting in the valve body. Relief areas, cut into the surface of the liner, permit valve operation with low torque and low unit pressures. Construction minimizes possibility of seepage, port blockage, and deformation of the liner by extrusion into the plug ports. *Patent* 2,782,550 *assigned to Duriron Co. Inc. by Deas Sinkler.*

Valve actuator, employing a modified rack and pinion mechanism, imparts simultaneous rotational and linear motions to plug-type valve stems. Continuous rotation of the mechanism pinion first moves the valve plug from its seat, moves it to a new position, and then reseats it. Construction of the actuator provides for greater mechanical advantage for unseating the valve in one operational position than in another. *Patent* 2,748,605 *assigned to Cameron Iron Works Inc. by Herbert Allen and Madden T. Works.*

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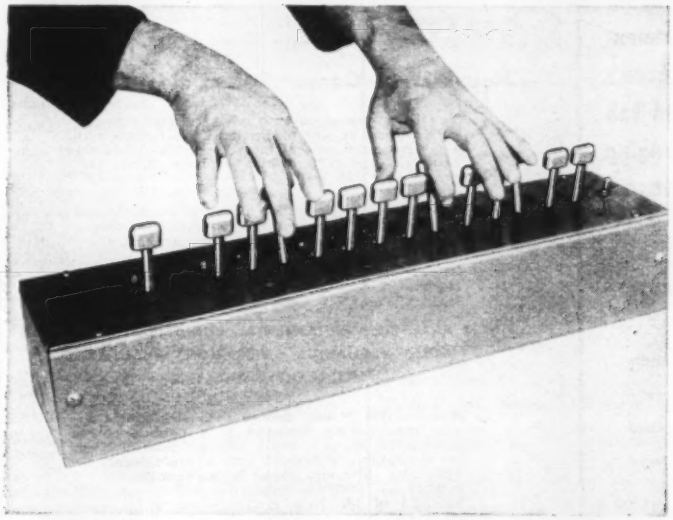

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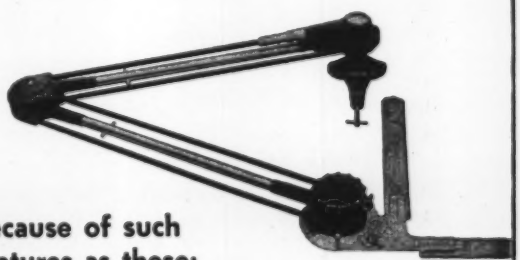

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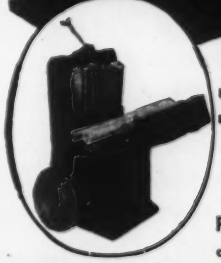

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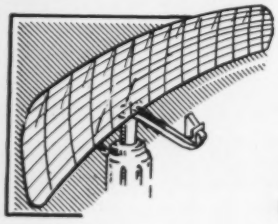

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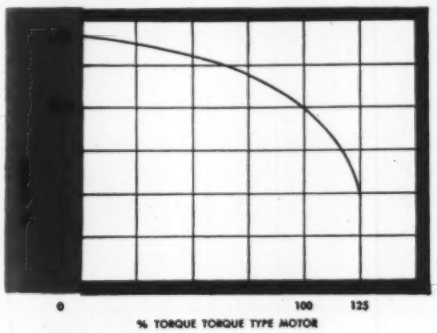

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POWER: AC 50 to 60 cycles.

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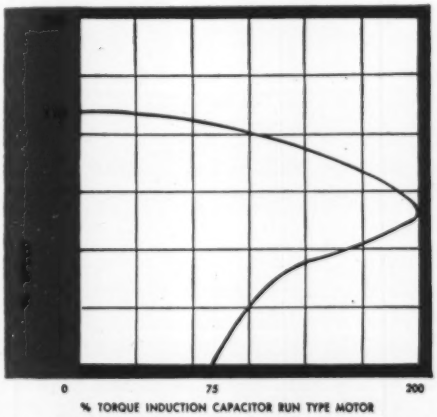
1. No Load speed is determined by number of poles, with a No Load slip of approximately 5%.
2. Full Load speed decreases with an increasing load. Designed to operate at approximately 30% full load slip.
3. No breakdown torque.
4. Starting torque high approximately 125% full load.



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POWER: AC 50 to 60 cycles.

CHARACTERISTICS:

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2. Constant Full Load speed, with a full load slip of approximately 10%.
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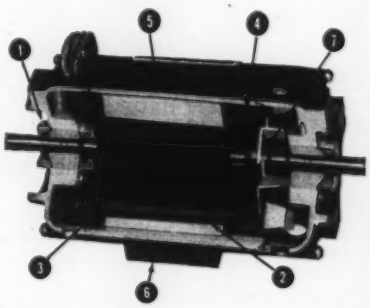

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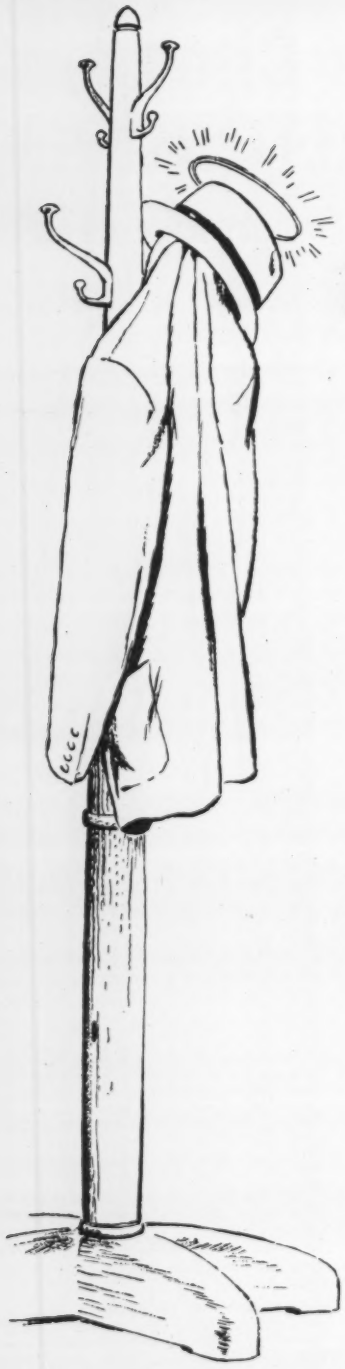

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Construction .. Open, enclosed, splash-proof, fan-cooled, explosion-proof, special purpose.

Speeds..... Single-speed, multi-speed, and variable speed.

Installation.... Horizontal or vertical, with or without flanges and other features.

Power Drive Features..... Electric brakes (2 types)—5 types of gear reduction up to 432 to 1 ratio. Mechanical and electronic variable speed units—fluid drives—every type of mounting.

THE MASTER ELECTRIC COMPANY, Dayton 1, Ohio